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**FOCUSED REMEDIAL INVESTIGATION REPORT**  
**FOR**  
**RICHARDSON FLAT TAILINGS SITE**

**SITE ID: UT980952840**

**December 17, 2002**

**Prepared for:**

**United Park City Mines Company  
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**Table of Contents**

<b>List of Figures.....</b>	<b>III</b>
<b>List of Tables .....</b>	<b>IV</b>
<b>List of Appendices.....</b>	<b>IV</b>
<b>EXECUTIVE SUMMARY .....</b>	<b>1</b>
<b>1.0 INTRODUCTION.....</b>	<b>3</b>
1.1 Purpose of Report .....	3
1.2 Site Background .....	3
1.2.1 Site Description.....	4
1.2.2 Site History .....	4
1.2.3 Previous Investigations .....	5
1.2.3.1 Air Monitoring Investigations .....	7
1.2.3.2 Tailings Cover Investigations.....	8
1.2.3.3 Studies of Tailings Impoundment Integrity and Stability .....	8
1.2.3.4 Groundwater Investigations.....	9
1.2.3.5 Investigations of Surface Water Quality .....	12
1.3 Report Organization .....	14
<b>2.0 STUDY AREA INVESTIGATION.....</b>	<b>14</b>
2.1 Surface Water .....	14
2.2 Groundwater .....	15
2.2.1 Offsite Monitoring Wells.....	16
2.2.2 Onsite Monitoring Wells (South of Diversion Ditch).....	17
2.2.3 Floodplain Tailings .....	17
2.3 Onsite Soils Cover Sampling.....	18
2.4 Offsite Soils Cover sampling.....	18
2.5 Sediment Sampling.....	19
2.6 Tailings .....	19
2.7 Tailings South of the Diversion Ditch.....	19
2.8 Background Soil Sampling.....	21
2.9 Study Area Boundary Sampling.....	21
<b>3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA.....</b>	<b>22</b>
3.1 Physical Characteristics.....	22
3.1.1 Surface Features.....	22
3.1.2 Meteorology .....	23
3.1.3 Surface Water Hydrology .....	23
3.1.4 Groundwater Hydrogeology .....	24
3.1.5 Onsite Soils Cover .....	26
3.1.6 Offsite Soils Cover.....	27
3.1.7 Sediment Sampling .....	27
3.1.8 Tailings .....	27
3.1.9 Tailings South of the Diversion Ditch .....	28
3.1.10 Background Soil Sampling .....	29
<b>4.0 NATURE AND EXTENT OF CONTAMINATION .....</b>	<b>29</b>
4.1 Surface Water .....	30

# **DRAFT**

4.1.1	Background Water Quality .....	31
4.1.2	South Diversion Ditch.....	32
4.1.3	Silver Creek .....	33
4.1.4	Floodplain Tailings Area .....	33
4.1.5	Surface Water Summary .....	34
4.2	Ground Water .....	34
4.2.1	Silver Creek Alluvial Aquifer.....	35
4.2.2	Groundwater in Tailings South of the Diversion Ditch .....	35
4.2.3	Floodplain Tailings.....	36
4.2.4	Groundwater Results Summary .....	36
4.3	Onsite Soil Cover.....	37
4.4	Offsite Soils Cover .....	38
4.5	Sediment Sampling.....	40
4.6	Tailings .....	41
4.7	Tailings South of the Diversion Ditch.....	41
4.8	Background Soil Sampling.....	43
4.9	Study Area Boundary Sampling.....	44
5.0	<b>CONTAMINANT FATE AND TRANSPORT .....</b>	<b>45</b>
5.1	Introduction .....	45
5.2	Sources and Primary Contaminants of Concern.....	46
5.2.1	General Characteristics of Tailings.....	46
5.2.2	Chemical Characteristics of Tailings.....	47
5.2.3	Mineralogy of Tailings .....	47
5.2.4	Leaching Characteristics of Tailings .....	48
5.3	Contaminant Characteristics and Transport Parameters.....	49
5.3.1	Metals Behavior and Relevant Fate and Transport Processes .....	49
5.4	Release Mechanisms and Potential Routes of Migration .....	52
5.4.1	Leaching of Metals from Tailings Impoundment.....	52
5.4.2	Leaching of Metals from Tailings Outside Impoundment.....	53
5.4.3	Transport of Metals from South Diversion Ditch to Wetlands.....	53
5.4.4	Migration of Metals from South Diversion Ditch and Wetlands to Silver Creek	56
5.4.5	Interaction of Wetlands with Silver Creek Alluvial Aquifer .....	56
5.4.6	Transport of Metals Between Upper Aquifer and Silver Creek Alluvial Aquifer	57
5.4.7	Interaction Between Silver Creek and Silver Creek Alluvial Aquifer.....	58
5.5	Contaminant Persistence and Source Stability .....	59
5.5.1	Controls on Tailings Chemical Stability.....	61
5.5.2	Acid Generation Analysis.....	61
5.5.3	Neutralization Potential .....	63
5.5.4	Chemical Stability of Sediments in South Diversion Ditch and Wetlands...	63
6.0	<b>BASELINE RISK ASSESSMENT .....</b>	<b>64</b>
7.0	<b>SUMMARY AND CONCLUSIONS .....</b>	<b>65</b>
7.1	Summary of Nature and Extent of Contamination .....	65
7.0	<b>REFERENCES.....</b>	<b>68</b>

# **DRAFT**

## **List of Figures**

- 1-1 Site Location Map
- 1-2 Site Vicinity Map
- 1-3 Site Features and Boundary Map
- 1-4 Historical Surface and Groundwater Sample Location Map
  
- 2-1 Surface and Groundwater Sample Location Map
- 2-2 Floodplain Area Sample Location Map
- 2-3 Soil Boring Location Map
- 2-4 Onsite Soil Cover Sample Location Map
- 2-5 Site Wind Rose
- 2-6 Offsite Soil Cover Sample Location Map
- 2-7 Sediment Sample and Tailings Test Pits Location Map
- 2-8 Tailings South of the Diversion Ditch Sample Location Map
- 2-9 Background Soil Sample Location Map
- 2-10 Study Area Boundary Sample Location Map
  
- 3-1 Tailings South of Diversion Ditch Cover Map
  
- 4-1 Dissolved Zinc Time Series, Surface Water
- 4-2 Total Lead and Zinc Time Series, Groundwater
- 4-3 Floodplain Tailings Area Potentiometric Surface Map
- 4-4 Silver Creek Area Hydrogeologic Cross Sections
- 4-5 Onsite Soils Cover Analytical Results
  
- 5-1 Schematic Model of Contaminant Transport Pathways
- 5-2 pH/Eh Plot
- 5-3 Surface Complexation of Dissolved Metal Ions
- 5-4 Time Series Plot of Dissolved Zinc Concentrations in Upper Aquifer South of Tailings Impoundment
- 5-5 Dissolved Zinc Concentrations in South Diversion Ditch
- 5-6 Metals Concentrations in South Diversion Ditch Sediments
- 5-7 Comparison of Trace Metal Ratios in Tailings and Diversion Ditch Sediments
- 5-8 Zinc Concentrations in Sediment and Water Along South Diversion Ditch
- 5-9 Lead Concentrations in Sediment and Water Along South Diversion Ditch
- 5-10 Plots of Dissolved Zinc vs. Key Chemical Parameters
- 5-11 Temperature and pH in Water Along South Diversion Ditch
- 5-12 Cation Exchange Capacity vs. Metals Concentrations in South Diversion Ditch Sediments
- 5-13 Piper Plot
- 5-14 Time Series Plot of Dissolved Zinc Concentrations in Silver Creek Alluvium
- 5-15 Histogram of Dissolved Zinc Concentrations

# **DRAFT**

## **List of Tables**

- 1-1 Richardson Flat Historical Groundwater Analytical Results
- 1-2 Comparison of 1985, 1992 and 1998 Groundwater Data
- 1-3 Historical Surface Water Analytical Results
- 1-4 1999 Surface Water Data
  
- 2-1 Surface and Groundwater Sampling Frequency
  
- 3-1 Surface and Groundwater Field Data
- 3-2 Onsite Soil Cover Thickness
  
- 4-1 Surface Water Analytical Results
- 4-2 Low Detection Limits Hg Water Analytical Results
- 4-3 Screening of Dissolved Metal Concentrations in Surface Water
- 4-4 Background Surface Water Data
- 4-5 Floodplain Tailings Surface and Groundwater Analytical Results
- 4-6 Screening of Floodplain Tailings Area Metal Concentrations
- 4-7 Groundwater Analytical Results
- 4-8 Screening of Total Metals Concentrations in Groundwater
- 4-9 Onsite Soil Cover Analytical Results
- 4-10 Offsite Soil Cover Analytical Results
- 4-11 Sediment Analytical Results
- 4-12 Tailings Analytical Results
- 4-13 Soil pH Analytical Results
- 4-14 Tailings South of the Diversion Ditch Analytical Results
- 4-15 Background Soil Analytical Results
- 4-16 Background Soil Data
- 4-17 Study Area Boundary Analytical Results
  
- 5-1 Summary of Chemistry Data for Tailings
- 5-2 Summary of Mineralogy Data for Tailings
- 5-3 Synthetic Precipitation Leaching Procedure (SPLP) Results
- 5-4 Acid – Base Potential Results
- 5-5 Cation Exchange Capacity Results
- 5-6 Comparison of Mineralogy of Tailings and South Diversion Ditch Sediments

## **List of Appendices**

- Appendix 1 Preliminary Hydrogeologic Review of Richardson Flats Tailings Site
- Appendix 2 Monitoring Well and Soil Boring Logs
- Appendix 3 Tailings South of the Diversion Ditch Test Pit Logs
- Appendix 4 Analytical Results and Data Validation Report
- Appendix 5 Hydrogeologic Review of Richardson Flat Tailings Site

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## **EXECUTIVE SUMMARY**

This Focused Remedial Investigation (RI) Study Report details the results of the site characterization activities conducted at the Richardson Flat Tailings Site near Park City, Utah (the "Site"). The Site is an inactive mill tailings impoundment owned by United Park City Mines Company ("United Park"). United Park conducted the RI pursuant to an Administrative Order on Consent for a Focused Remedial Investigation /Feasibility Study, dated September 28, 2000, U. S. EPA Docket No. CERCLA-8-2000-19 (the "AOC"). The work was performed in accordance with the RI Workplan and Sampling and Analysis Plan ("SAP") that was prepared by United Park, in coordination with and approved by the U. S. Environmental Protection Agency (the "EPA") and the Utah Division of Environmental Response and Remediation (the "UDERR").

The Site is not listed on the National Priorities List, but had previously been proposed for listing by the EPA in 1988 and 1992. In 1999, the EPA and United Park initiated discussions regarding the additional site characterization work that would be needed to assess contamination conditions at, and remedial alternatives (if any) that may be required for the Site. Those discussions resulted in the issuance of the AOC and the performance of the RI work.

The RI sampling activities were conducted during the period of April 2001 to July 2002. Soil, surface water, groundwater, sediment, and tailings samples were collected and analyzed. The RI study Report presents the findings from these data gathering efforts, as well as certain data gathered from previous investigations conducted earlier by United Park and the EPA. The key findings from the RI activities, which are described in greater detail in the RI Study Report, include the following:

- On-site soils data indicate that the tailings cover is greater than one foot deep on the southern half of the impoundment, and more that six inches deep on the northern half of the impoundment. Except for a few localized areas, average lead concentrations in surface cover soils are less than 400 ppm. Data collected from soils in areas outside of the tailings impoundment area indicate the extent of wind-blown tailings is generally limited to areas immediately adjacent to the tailings impoundment area.
- Surface and groundwater samples were collected from an adjacent and upstream area owned by United Park, referred to as the "Floodplain Tailings" area, to provide a better understanding of shallow groundwater and surface water conditions in and near Silver Creek as required in the AOC. The data demonstrate that offsite sources of metals contamination appear to be impacting surface and groundwater quality in and near Silver Creek upstream and westerly of the Richardson Flat tailings impoundment. Water elevation and water quality data indicate that the Floodplain Tailings appear to be contributing some, but not all, of certain metals contamination to Silver Creek surface and groundwater systems in the area adjacent to and within Silver Creek west of the main Richardson Flat

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impoundment. Other sources of metals contamination located upstream of the Site are also impacting water quality in Silver Creek, as well. The Floodplain Tailings are part of the Upper Silver Creek Watershed Investigation.

- Groundwater at the Site has been detected in tailings both inside and outside of the impoundment area, in shallow alluvial aquifers beneath the Site and in the Silver Creek alluvial aquifer. Based on hydrogeologic studies, there appears to be no hydraulic connection between the groundwater found in the impounded Richardson Flat tailings and in the underlying shallow aquifers or within the Silver Creek alluvial aquifer. Groundwater quality data indicate that the alluvial aquifer underlying Silver Creek is not chemically similar to groundwater encountered in the tailings, or to surface water collected from the South Diversion Ditch.
- Sample data show that the diversion ditch sediments contain metals at all locations sampled, and that a transfer of metals from the sediments to surface water does not appear to be occurring with the diversion ditch.
- Tailings data indicate that there are more alkaline-generating compounds in the tailings than acid-generating compounds. The average pH of the tailings is 7.5 Su. Thus, under current operating conditions, it is unlikely that the tailings will become acidic. Data obtained from unsaturated tailings indicate that metals, such as lead and zinc, have a potential to leach from tailings under unsaturated conditions. However, groundwater data collected from wells completed in tailings at the site suggest that any metals that may have previously leached from unsaturated tailings would have since become immobilized upon encountering underlying saturated tailings.

EPA has conducted a Baseline Human Health Risk Assessment ("BHHRA") utilizing the data obtained from the RI and prior investigations. The results of the BHHRA indicate that the Site does not present a risk to recreational visitors under current land use designations. EPA will be conducting an Ecological Risk Assessment ("ERA"), following United Park's collection of ecological samples in the spring of 2003. When the ecological data are available, the RI report will be revised and finalized. Thereafter, the EPA will determine final Preliminary Remediation Goals for both human health and ecological receptors for the Site.

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### **1.0 INTRODUCTION**

This Focused Remedial Investigation (RI) Study Report details the results of site characterization activities conducted as part of a Focused Remedial Investigation and Feasibility Study (Focused RI/FS) at the Richardson Flat Tailings Site (The "Site") near Park City, Utah. The Site is an inactive mill tailings impoundment owned by United Park City Mines Company (United Park). United Park is conducting the Focused RI/FS pursuant to the Administrative Order on Consent (AOC) for a Focused Remedial Investigation/Feasibility Study, dated September 28, 2000, U.S. EPA Docket No. [CERCLA-8-2000-19]. The Focused RI/FS Work Plan (RMC, 2000), as referenced in this report was approved by the United States Environmental Protection Agency Region VIII (EPA) on September 28, 2000. The sampling and associated analytical analyses performed during this study were conducted in accordance with the Sampling and Analysis Plan (SAP) dated February 20, 2001 (RMC, 2001). The Sampling and Analysis Plan (SAP) was approved by the United States Environmental Protection Agency Region VIII (EPA) on March 10, 2001.

This report includes the relevant portions of a Remedial Investigation. As requested by EPA, the format of this report follows the suggested RI Report format outlined *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (U.S. EPA 540/G-89/004, 1988). Section titles follow the suggested outline where applicable.

#### **1.1 Purpose of Report**

The purpose of this report is to document results of a focused remedial investigation and incorporate findings from previous site investigations conducted by others at the Site. The purpose of the Remedial Investigation is to assess the risk to the environment and human health associated with past mining related activities at the Site. There have been multiple previous investigations regarding potential impacts to human health and the environment from site materials, this document focuses on data gaps from previous investigations.

#### **1.2 Site Background**

This section details the general characteristics of the Site. The Site history is presented as well as a synopsis of previous site investigations.

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### **1.2.1 Site Description**

The property is owned by United Park and consists of approximately 650 acres in a small valley in Summit County, Utah, located one and one-half miles northeast of Park City, Utah (Figure 1-1). The tailings impoundment covers approximately 160 acres in the northwest corner of the Property and lies within the northwest quarter of Section 1 and northeast quarter of Section 2, Township 2 South, Range 4 East, Summit County, Utah (Figure 1-2). Figure 1-3 shows the Site configuration, topography and boundary.

### **1.2.2 Site History**

United Park was formed in 1953, with the consolidation of Silver King Coalition Mines Company and Park Utah Consolidated Mines Company, both publicly traded mining companies at the time. Tailings were first placed at the Site prior to 1950. The mill tailings present at the Site consist mostly of sand-sized particles of carbonate rock with some minerals containing silver, lead, zinc and other metals. While few specific details are known about the exact configuration and operation of the historic tailings pond, certain elements of prior operations are apparent. From time to time, tailings were transported to the Site through three distinct low areas on the southeast portion of the Site. Over the course of time, tailings materials also settled out into these three low areas that were ultimately left outside and south of the present impoundment area as constructed in 1973-74. An embankment constructed along the western area of the Site also appears to have been in place as part of the original design and construction of the tailings pond, but few details are known of the original embankment.

In 1970, Park City Ventures (PCV), a joint venture partnership between Anaconda Copper Company (Anaconda) and American Smelting and Refining Company (ASARCO), entered into a lease agreement with United Park to use the Site for disposal of additional mill tailings resulting from renewed mining in the area. PCV contracted with Dames & Moore to provide construction specifications for reconstructing the Site for continued use as a tailings impoundment (Dames & Moore, 1974). The State of Utah approved PCV's proposed Site operations based on Dames & Moore's design, construction, and operation specifications. Before disposing of tailings at the Site, PCV installed a large, earth embankment along the western edge of the existing tailings impoundment and constructed perimeter containment dike structures along the southern and eastern borders of the impoundment to allow storage of additional tailings (See Figure 1-3). PCV also installed a diversion ditch system along the higher slopes north of the impoundment and outside of the containment dike along the east and south perimeter of the impoundment

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to prevent surface runoff from the surrounding land from entering the impoundment. PCV also installed groundwater monitoring wells near the base of the main embankment, as part of the required approval process by the State of Utah.

PCV conveyed tailings to the impoundment by a slurry pipeline from its mill facility located south of the Site. Over the course of its operations, PCV disposed of approximately 420,000 tons of tailings at the Site. In addition to developing construction specifications for the Site, Dames & Moore also provided PCV with design specifications for the embankment as well as operating requirements for the tailings pond and slurry line, that were also approved by the State of Utah as a requirement for operating the Site. Dames & Moore recommended, among other things, that PCV operate the slurry line in such a way to deposit tailings around the perimeter of the tailings impoundment and moving towards the center of the impoundment (Dames & Moore, 1974 at p. 21). This is a common operating practice in the industry. Unfortunately, PCV failed to follow the Dames & Moore requirement and operated the slurry line in such a way that a large volume of tailings were placed near the center of the impoundment in a large, high-profile, cone-shaped feature. PVC also failed to construct the main embankment in accordance with specifications provided by Dames and Moore. After cessation of operations by Noranda in 1982, the presence of this cone-shaped feature of the tailings pond resulted in the prevailing winds cutting into the tailings and the tailings materials becoming wind-borne. Had the slurry line been operated according to the Dames & Moore specifications, the high-profile tailings cone would not have existed and prevailing winds would not have been a significant potential exposure pathway at the Site. Between 1980 and 1982, Noranda Mining, Inc. (Noranda) leased the mining and milling operations and placed an additional, estimated 70,000 tons of tailings at the Site. No new tailings have been placed at the Site since Noranda ceased its operations. A soil cover has been placed on the impoundment.

### **1.2.3 Previous Investigations**

Since the 1970s, PCV, Noranda, EPA, and United Park have conducted numerous environmental investigations relating to the Site. Beginning in the 1970s, PCV conducted groundwater, tailings pond, and embankment design studies that focused on the construction of containment structures that would accommodate additional tailings. In 1980, Noranda conducted studies to determine the current condition of the impoundment and the potential for future enlargement of the impoundment. In the 1980s and early 1990s, EPA conducted studies of groundwater, surface water, and air quality to determine whether Site contaminants posed threats to human health or the environment to require listing of the Site on the

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National Priorities List (NPL). United Park initially conducted studies in response to EPA's proposal to list the Site on the NPL. More recently, United Park has obtained data focusing on the characterization of Site hydrogeology and surface water quality.

EPA has proposed listing the Site on the NPL on two occasions. In 1988, EPA proposed listing the Site on the NPL based on the Site's Hazardous Ranking System (HRS) score. After considering public comments, EPA ultimately declined to list the Site by removing it from the proposed NPL. By 1992, the HRS scoring system had been revised and at that time, EPA conducted additional studies and rescored the Site and again proposed that the Site be placed on the NPL. Based on the new proposal to list the Site, the EPA Emergency Response Branch (ERB) conducted additional investigations on the Site and determined that conditions did not warrant emergency removal action. In 1994, the Agency for Toxic Substances and Disease Registry (ATSDR) in their *Preliminary Public Health Assessment Addendum on the Richardson Flat Tailings* found that the Site posed "no apparent public health hazards due to past or present exposure." The ATSDR did, however, consider Richardson Flat an "indeterminate public health hazard" in the future due to the potential for residential development on or near areas where significant levels of contamination may be found. United Park's future land use plan includes provisions that residential development will not occur in these areas.

The EPA has yet to list the Site on the NPL, but the Site's listing on CERCLIS remains in effect. While no formal regulatory action has occurred with respect to the Site since the second proposed listing, United Park has continued its efforts to investigate and close the Site by improving the soil cover, maintaining the diversion ditches, and collecting surface water and groundwater data.

This section summarizes past investigation activities and existing Site data. The reports and data from these investigations were very useful in determining the scope of additional investigative activities needed to bring final closure to the Site. From 1985 to 1988 and from 1992 to 1993, the EPA conducted and reported on investigations at the Site. Because past investigation activities by PCV, Noranda and United Park were performed without EPA oversight and with an unknown degree of QA/QC, the results from such investigations are incorporated into this Focused RI as screening level data.

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### **1.2.3.1 Air Monitoring Investigations**

Due to concerns over wind-blown tailings resulting from the cone-shaped tailings feature created by past operators, EPA conducted air monitoring investigations on two separate occasions. Due to United Park's subsequent placement of the full, vegetated clay soil cover, data from these investigations are no longer directly relevant but are reported here to support United Park's proposed study of offsite wind blown tailings.

In 1985, when approximately 40 percent of all of the tailings on the Property had been covered with the soil cover, Ecology and Environment, Inc. (E&E), a contractor working for EPA, collected air data. Four high volume air samplers were located on or immediately adjacent to the tailings impoundment and one was located approximately one-half mile southeast of the Site. Data were collected at the Site over a five-day period and the filters from the samplers were analyzed for arsenic, cadmium, lead and zinc. A meteorologic station was installed at the Site and wind direction, air temperature, barometric pressure and relative humidity data were collected. The prevailing wind direction measured at that time was from the northwest to southeast (E&E, 1987 at p. 3). According to E&E's analytical data, increases were noted for all metals measured in downwind versus upwind monitoring locations. Review of the data in Table 1 of the 1987 E&E report shows that 52% of arsenic, 92% of cadmium, 17% of lead and 14% of zinc measured on the air filters at the Site were below the laboratory's detection limits.

E&E again conducted air monitoring in 1992 at five locations. The installation of the cover within the impoundment had progressed to the point where all of the exposed tailings had been covered, with the exception of one area of tailings where salt grass and other native plant species were growing and had stabilized the tailings. These new air monitoring activities showed no detectable levels of arsenic, cadmium or lead. Trace levels of zinc were detected in four of the seventeen samples collected. There are no ambient air quality standards for zinc. The significant reduction in the concentration of target analytes from these two air-monitoring programs can be explained by United Park's efforts to cover the remaining areas of the impoundment. Since 1992, all of the exposed tailings in the impoundment have been covered, including the area where salt grass was growing.

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### **1.2.3.2 Tailings Cover Investigations**

As part of the EPA ERB investigations in 1992, E&E conducted a survey of the depth of soil cover. E&E measured the depth of cover at 29 locations on a grid pattern of 400 x 400 feet. These locations are depicted on Figure 2, Appendix B of the E&E report (E&E, 1993). According to the E&E report (1993), a visual contrast was apparent between the soil cover and the gray colored tailings beneath the cover. X-ray fluorescence (XRF) measurements for lead were taken at select locations to confirm the visual contrast where the distinction was not clear (see E&E, 1993, Appendix B, Table 1, for the soil cover data). E&E reported that much of the tailings either had soil or salt grass covering the exposed tailings. Generally, data from the 1993 study shows that the soil cover varied in thickness from less than six inches to fourteen inches in depth in the areas E&E tested. E&E did not test areas of thick cover, where as much as three feet of cover were present. Of the 29 points E&E measured, only one location had no soil or salt grass present. Subsequent to E&E's work, United Park has placed additional soil cover in this and other areas of the impoundment to improve the tailings cover and support Site closure.

As part of the hydrogeologic investigation by Weston (1999, as discussed in Section 1.2.3.4 below), data were collected on the soil characteristics of the tailings cover. Samples of the tailings cover soil were tested to determine classification and hydraulic characteristics. Soil cover samples were collected from three representative locations over the Site and were tested for moisture content and dry density. Based on this testing, the soil cover was classified as lean clay with sand. Two of the three samples were also submitted for laboratory analysis to determine permeability. Laboratory testing indicated that the cover soil is essentially impermeable, with permeability's ranging from 3 to 7 x 10<sup>-8</sup> cm/sec. These values roughly correspond to permeability's typically measured in clay liner systems that are required to be installed at hazardous waste landfills. X-ray diffraction (XRD) analysis of select samples indicated that the soil cover clay mineralogy closely matched the XRD peaks for illite and kaolinite. Kaolinite was the most prevalent clay mineral, is stable with little tendency for volume change when exposed to water. Illite generally more plastic than kaolinite, does not expand when exposed to water (Weston, 1999 at p. 4).

### **1.2.3.3 Studies of Tailings Impoundment Integrity and Stability**

In 1974, PCV hired Dames & Moore to conduct an investigation of the Site and to develop construction specifications for reconstructing the embankment in order to accommodate the placement of additional tailings materials. While PCV raised and reconstructed the embankment and installed the containment

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dike system, according to subsequent work performed by Dames & Moore for Noranda, PCV did not appear to follow the design specifications developed by Dames & Moore. In 1980, Dames & Moore conducted an impoundment integrity and stability investigation for Noranda, current operator of the Richardson Flat tailings impoundment at the time. The objective of that investigation was to assess the overall condition and usefulness of the existing facilities and to determine what measures would be required for long-term tailings disposal (Dames & Moore, 1980 at p. 1). Dames & Moore noted several construction flaws during the 1980 investigation, specifically noting that the main embankment was oversteepened in some locations. Dames & Moore concluded that while it did not have any immediate concerns regarding the stability of the main embankment and containment dikes, it did have concerns regarding the use of the Site to dispose of additional tailings. In 1992, E&E examined the tailings impoundment for EPA noting that the main embankment generally was not constructed according to the 1974 recommendations of Dames & Moore. E&E concluded that there appeared to be no immediate threat of gross failure of the tailings containment structure. The remedial feasibility study conducted upon the completion of this remedial investigation will address the long-term stability of the embankment.

### **1.2.3.4 Groundwater Investigations**

In the early 1970s, PCV began to collect groundwater data at the Site. Since that time, both EPA and United Park have investigated groundwater conditions at the Site. In 1973, PCV installed three monitoring wells (MW-1, MW-2 and MW-3) at the bottom of the main embankment. In 1976, PCV installed three additional wells (MW-4, MW-5, and MW-6). These wells are referred to as Wells 1 through 6 on Figure 1-4. It appears that PCV buried monitoring well MW-2 in 1976 during work on the embankment. Thus, five groundwater monitoring wells are remaining near the toe of the embankment. The boring and well completion logs for these five wells are summarized below:

MW-1 was drilled to a total depth of 35 feet below the ground surface (bgs). Volcanic bedrock was encountered from 14.5 feet bgs to the total depth drilled. Well screen and gravel pack were installed from 24 to 34 feet bgs.

MW-2 was drilled to a total depth of 21 feet bgs, bedrock was encountered from 11 to 21 feet bgs. Well screen and gravel pack were installed from 3 to 9.5 feet bgs. (This well was destroyed during work on the embankment in 1976).

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MW-3 was drilled to a depth of 29 feet bgs; and bedrock was encountered from 5.8 to 31 feet bgs. Well screen and gravel pack were installed from 2.5 to 25 feet bgs.

MW-4, MW-5, and MW-6 were drilled to total depths of 4.0 feet, 6.1 feet and 6.1 feet bgs, respectively. Boring and completion logs for these wells are not available.

Since 1973, PCV, and later, United Park when possible, have collected data quarterly from these embankment wells. Table 1-1 presents groundwater data collected by United Park from 1982 to 1987 and 1991 to 1998 from these monitoring wells.<sup>1</sup> Data presented in Table 1-1 shows that generally water quality has steadily improved in the monitoring wells generally over time. However, there are some readily apparent anomalies. For instance, in September of 1998, pH levels between 2.7 and 4.1 were noted for MW-4 and MW-5, respectively. Although these are relatively low pH values and could be indicative of a change in water chemistry in these two wells, it is interesting to note that dissolved zinc concentrations measured in MW-4 for the same time period were an order of magnitude lower than for the measurement in June of 1998 when the pH was 7.1. In MW-5, the dissolved zinc concentrations were similar between June and September of 1998, but the pH values were 7.7 and 4.1, respectively. This may indicate that the pH meter was not functioning correctly. Both of these wells are completed within the first six feet of the ground surface. Thus, it is likely that the water that is monitored here is vadose zone water that is highly oxidigenated. The oxidigenated water will have a highly variable water chemistry depending on the hydrogeologic characteristics of the subsurface soils. A definitive trend in the water chemistry is not apparent. In 1985, E&E collected groundwater samples from one upgradient well and two wells located downgradient of the main embankment.<sup>2</sup> E&E installed the upgradient RT-1 monitoring well. The two downgradient wells were existing wells installed by PCV around 1974 and 1975.

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<sup>1</sup> Groundwater data from the main embankment wells for the years 1988 to 1990 are not readily available to United Park and as a result are not reported herein. United Park is attempting to locate data from 1988 to 1990. If it is located it will be reported it will be reported in a future draft of this report.

<sup>2</sup> According to the E&E sampling report, United Park wells MW-1 and MW-2 were sampled. This appears to be in error. MW-1 was most likely sampled by E&E, along with MW-5 or MW-6. MW-2 was believed to have been buried during the installation of MW-4, MW-5 and MW-6 (see Plate 1, Appendix A). United Park's 104(e) response to EPA in 1988 did not contain data for MW-2. The data record submitted to EPA covered the time period from 1982 to 1987. Therefore, E&E could not have sampled MW-2 at that time.



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In 1992, EPA directed E&E to conduct an additional groundwater investigation. The 1992 groundwater data revealed a similar trend as shown in the 1985 E&E study. E&E collected groundwater samples from the Site at three locations, referred to as RF-GW-04 (EPA well RT-1), RF-GW-05 (United Park location MW-1) and RF-GW-09 (United Park location MW-6). Table 1-2 compares the data collected by EPA in 1985 and 1992 with data collected from the same wells by United Park in 1998. Review of the data collected from upgradient well RT-1 in 1985 and 1992 reveals that water quality appears to have deteriorated at this location over time. Some dissolved metal concentrations have increased from 1984 to 1992. The 1992 data contains some anomalies that suggest either the sample was contaminated or there were some analytical errors; dissolved metal concentrations are greater than the total concentrations for antimony, copper, and silver. The change in water chemistry over the eight-year time period is difficult to explain at this time. The well is completed in two aquifers, and thus, there is likely a mixing of water between the two water bearing zones. During site visits in early 1999, it had been observed that the wellhead integrity had been compromised, apparently by vandals. It is not known if this damage had occurred in 1992. As a result, surface contamination may have impacted water quality. The well was installed by E&E in 1984, and therefore, is the property of the EPA. United Park does not sample this well. United Park will abandon the well according to proper procedures because of the intermixing of the two aquifers and the breach in the wellhead integrity.

In 1999, United Park hired Weston Engineering, Inc. (Weston) to conduct a supplemental hydrogeological investigation of the Site. This groundwater study represented the most extensive groundwater investigation conducted to date to better understand groundwater systems on at the Site. Weston evaluated historical Site and regional data to derive a hydrogeological conceptual Site model (See Appendix 1). In the course of its investigation, Weston installed eleven piezometers throughout the Property (See Plate 1, Appendix 1). Boring logs from the piezometer installation verified the existence of two aquifers at the Site. Water level data collected from the piezometers indicate that the two aquifers are confined and are separated from one another by a significant layer of stiff, clay-rich material. The upper aquifer is overlain by approximately 15 feet of reddish-brown mixtures of silt and clay. An additional two to five-foot layer of clay-rich soil overlies this layer of clay-rich material (Weston, 1999, at p. 4). The local geology has greatly influenced the types of soils that have developed at the Site. The altering and weathering of Keetley volcanics, which form the surrounding hills, have provided the source material for soil development. The abundant clays that result from the alteration and weathering of the Keetley volcanics form the bulk of the natural alluvial material as well as the soil at the Site. Percolation tests

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conducted on this volcanic soil that was borrowed to cover the tailings within the impoundment indicates that it has very low permeability,  $3 \text{ to } 7 \times 10^{-8} \text{ cm/sec}$ . Water level data collected after the installation of the piezometers and subsequent water level measurements generally indicate that the water levels in the two aquifers varies seasonally, with higher water levels occurring in the Spring.

The data reported by Weston was not available to earlier Site inspection teams and other agencies that previously evaluated the Site. Studies by Dames & Moore identified the presence of clays in the naturally occurring material at the Site. It was not until Weston's investigation that the extent and significance of the natural clay material underlying the Property was known. The existence of two to five feet of clay-rich topsoil and the presence of the large area of silt and clay that overly the upper aquifer represent a significant barrier to the vertical migration of any water from the saturated tailings.

### **1.2.3.5 Investigations of Surface Water Quality**

PCV, Noranda and United Park have collected surface water quality data at the Site since 1975. Data from 1982 to 1988 are presented in Table 1-3. Samples were collected from locations upstream and downstream of the confluence of the South Diversion Ditch with Silver Creek. Also, samples were collected from water that runs in the diversion ditch as it passes through the Site. Figure 1-4 shows the sample locations.

A review of the historical and recent data from these three sampling points demonstrates that since the time that United Park's regrading and covering of the banks of the South Diversion Ditch (1992-1993), water quality has steadily improved both in the South Diversion Ditch at the point where it leaves the Site and in Silver Creek below the Site (*See Figure 1-4*). The recent data also demonstrate that although some metals are present in upstream areas in the South Diversion Ditch, by the time water leaves the Site and discharges to Silver Creek, metal levels have decreased significantly.

In 1999, United Park initiated a surface water sampling program designed to characterize water chemistry in the South Diversion Ditch and Silver Creek near the Site. Table 1-4 presents the data collected in 1999 while Figure 1-4 shows the 1999 sample locations. Samples were collected at eleven locations in May and June of 1999 during the spring snowmelt and runoff season (designated RF-1 through RF-10 on Figure 1-4). Samples were collected and analyzed for full suite parameters as shown in Table 5.2 of the Workplan (RMC, 1999) at RF-1 and RF-3 (Figure 1-4) on the unnamed drainages that flow into the South

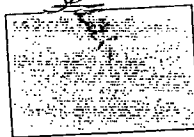
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Diversion Ditch. Samples were collected in May and June of 1999 at RF-2, RF-4, RF-5 and RF-6 on the South Diversion Ditch. Samples RF-2 and RF-6 were analyzed for full suite parameters (RMC, 1999) and RF-4 and RF-5 were analyzed for total and dissolved metals. Samples RF-7, RF-7-2, RF-8 were collected from Silver Creek and analyzed for full suite parameters. Location RF-9 is the ponded water that exists on the tailings impoundment this sample was analyzed for full suite parameters. Sample location RF-10 represents background water quality from the south unnamed drainage near the county road along the eastern boundary of the site. RF-10 was sampled one time and was not sampled in later sampling events. A flume was installed at sample location RF-3-2 to replace RF-10. Samples were collected monthly at three locations (RF-6, RF-7-2 and RF-8) from July to November of 1999. Full suite analyses consisted of major cations and anions, metals and field parameters. Target metals were arsenic, cadmium, chromium, copper, lead, mercury, selenium, silver and zinc. Field parameters were flow, pH, conductivity and temperature.

→ what the book is an aquatic wildlife std, that's hardness dependent  
Table 1-4 presents the 1999 data in three categories. The first category compares the data to aquatic wildlife criteria, the second category gives the general water chemistry data, and the third category compares the data to water quality standards for a Class 1C stream (this is the classification for Silver Creek). The aquatic wildlife standard is based on the hardness in the water. Therefore, the standard will have a different value depending on hardness at each location. Metal data presented in the first category are compared to hardness-dependent aquatic wildlife criteria. Protection of Aquatic Wildlife Criteria is the most stringent regulatory standard for comparison purposes. In other words, if the metal concentration is less than the aquatic wildlife criteria, then that metal concentration will be less than any other applicable water quality standard. Examination of the first category of data presented in Table 1-4 reveals that for all of the metals measured, only zinc exceeds the aquatic wildlife criteria. Zinc exceeded both the acute and chronic criteria in samples collected upstream in Silver Creek (RF-7 and RF-7-2) and downstream (RF-8) of the South Diversion Ditch confluence. Zinc concentrations measured in the diversion ditch (RF-6 and RF-6-2) were well below the aquatic wildlife criteria.

Mercury concentrations measured in 1999 were all below the laboratory detection limit of 0.0005 ppm at all of the sample locations. The acute aquatic wildlife criteria is 0.0024 ppm and the chronic criteria is 0.000012 ppm. Therefore, measured mercury concentrations were below the acute criteria. The laboratory detection limits were not sufficiently low enough to ascertain if the mercury concentrations are above the chronic criteria. EPA recently promulgated laboratory method 1631 that establishes a standardized procedure to measure mercury at the 2 to 3 part per trillion range.

July 15  
July 14  
June 15



### **1.3 Report Organization**

The organization of this report follows the suggested RI report format outlined in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (U.S. EPA 540/G-89/004, 1988). Section titles follow the suggested outline where applicable. Sections are subdivided using conventions presented in the Sampling and Analysis Plan (RMC, 2001) for each media of concern.

## **2.0 STUDY AREA INVESTIGATION**

This section details the Study Area investigation. Each media of concern was investigated as a separate entity. The media sampled is consistent with the Sampling and Analysis Plan (RMC, 2001) for the Site. The sampling methodology for each media of concern is presented in this section.

All samples were collected according to the RMC Standard Operating Procedures (SOP) presented in Appendix C of the SAP (RMC, 2001). Field and laboratory analytical parameters are shown on Table 2 of the SAP (RMC, 2001). Sample collection procedures were conducted according to procedures in Section 3.2 of the SAP (RMC, 2001). Analytical and laboratory procedures followed those described in Section 3.4 of the SAP (RMC, 2001).

Sample locations and groundwater elevation datum points were surveyed using Global Positioning Survey (GPS) and conventional survey techniques performed by a surveyor licensed by the State of Utah.

### **2.1 Surface Water**

Surface water samples were collected at ten (10) to three (3) locations (RF-1, RF-2, RF-3-2, RF-4, RF-5, RF6-2, RF7-2 RF-8, RF-11 and RF-12) depending on the flow regime on and near the Site as depicted on Figure 2-1. The sample locations were selected based on data collected in 1999 and 2000. The rationale for the sample locations was to provide a data set that will be complete enough to characterize seasonal water quality and quantity in the South Diversion Ditch, as well as the unnamed drainages flowing into the South Diversion Ditch and Silver Creek. Data from the unnamed drainages will provide limited background water chemistry data, the unnamed drainages only flow in response to snowmelt or significant storm events. Furthermore, the data were used to determine the effects of the Site on Silver

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Creek water chemistry and provide information to evaluate the source of elevated zinc concentrations found in the middle reach of the diversion ditch.

When possible, samples were collected monthly at each location through at least one complete seasonal time period. The sampling cycle was initiated in April 2001. A full round of twelve samples were not collected at five (5) locations due to a lack of flow: RF-1, RF-2, RF-3-2, RF-4 and RF-5. Sample locations RF-11 and RF-12 were added in the South Diversion Ditch during spring 2002, these sample locations were not presented in the SAP. Table 2-1 summarizes the months that samples were collected at each surface water sampling site.

An additional set of five (5) surface water sampling sites (FPT-SW1, FPT-SW2, FPT-SW3, FPT-SW4 and PH-SW1) were established in an area west of Silver Creek in the vicinity of the exposed tailings area referred to as the Flood Plain Tailings. These locations were not detailed in the SAP (RMC, 2001) however, sampling was conducted according to the protocols outlined for groundwater sampling in the SAP (RMC, 2001). The additional locations are presented on Figure 2-2. The sample locations were based on the need to assess surface water on the west side of Silver Creek.

In addition to the surface water sampling described above six (6) staff gauges (SG 1 through SG-6) were installed in spring 2002 throughout the Site. Surface water elevation data collected at the staff gauge locations was used to calculate surface water elevation data and groundwater flow directions. The staff gauge locations are presented in Figure 2-1.

## **2.2 Groundwater**

Five (5) shallow monitoring wells were installed during this investigation (RT-11, RT-12, RT-13, RT-14 and RT-15). The wells were installed to assess and monitor shallow groundwater conditions in and around the Site. Monitoring well locations are presented in Figure 2-1. Monitoring wells were installed according to procedures detailed in RMC SOP 3a and Section 3.1.2 of the SAP (RMC, 2001). The rationale for the selected monitoring well locations included sites that allowed United Park to monitor groundwater upgradient and downgradient of the Site on Silver Creek and groundwater conditions near the diversion ditch. Monitoring well logs are presented in Appendix 2.

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The wells installed by this study have been monitored on a monthly frequency since July 2001. The wells were monitored for a total of twelve months. Monitoring consisted of measuring depth to groundwater and field parameters (temperature, pH and conductivity) and collecting water samples from each well. Monitoring well sampling procedures are presented in Section 3.1.2 of the SAP (RMC, 2001).

Although the first round of groundwater sampling was conducted during the month of June 2001, the data from this month is not being used due to turbidity problems in the wells from incomplete well development (*See* RMC, 2002, Data Quality Assessment). The wells were redeveloped and sampled in July. The final round of groundwater sampling was conducted in the month of June 2002.

### **2.2.1 Offsite Monitoring Wells**

Two (2) monitoring wells were installed offsite (Figure 2-1). Monitoring Well RT-11 was installed adjacent to Silver Creek to the west of and upgradient of the impoundment area. RT-11 is being used to assess water quality in the shallow Silver Creek alluvial aquifer upgradient from the Site. Monitoring Well RT-12 was placed adjacent to Silver Creek west of and downgradient from the impoundment area. RT-12 was installed to assess and monitor water quality downgradient from the Site. These wells will enable United Park to determine the impacts of the Site on the Silver Creek alluvial aquifer.

Monitoring Well locations RT-11 and RT-12 were determined by ground conditions in the vicinity of Silver Creek, State Road 248 and the Rail Trail as well as utility (fiber optic) locations adjacent to the Rail Trail. Well locations were selected based on combination of data needs and ground conditions that would provide ample room for drilling.

Prior to the drilling and installing Monitoring Wells RT-11 and RT-12, a series of eight (8) soil borings were drilled using a geoprobe in the vicinity of proposed well locations (Figure 2-3). Boring logs are presented in Appendix 2. All soil borings were backfilled with bentonite chips upon completion. The borings were installed to gain a better understanding of the shallow Silver Creek alluvial aquifer and enabled site personnel to correlate conditions between the two offsite monitoring well locations. The correlation was completed to insure that both monitoring wells were installed in the same hydrogeologic horizons.

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### **2.2.2 Onsite Monitoring Wells (South of Diversion Ditch)**

Three (3) monitoring wells were installed onsite in the area south of the diversion ditch (Figure 2-1). The wells were placed to gain an understanding of groundwater conditions in the tailings located south of the diversion ditch. Monitoring wells RT-13 and RT-14 were installed in the eastern portion of the site. Monitoring well RT-15 was installed in the western portion of the site in a dry horizon to monitor future water level changes.

The onsite monitoring wells were installed near test pits excavated to evaluate the tailings south of the diversion ditch (Section 2.7). This methodology allowed for a full examination of adjacent hydrogeologic conditions prior to monitoring well installation.

### **2.2.3 Floodplain Tailings**

A series of sixteen (16) shallow monitoring wells were installed in an area of exposed tailings off site in the area west of Silver Creek referred to as the Floodplain Tailings. These wells were installed to help with the evaluation of the shallow Silver Creek groundwater aquifer in the area. These tailings are located on property owned by United Park, however, these tailings are not part of the Site and should be addressed by the watershed group. Of these wells a series of six (6) shallow monitoring wells (FPT-2B, FPT-4A, FPT-7A, FPT-8A, FPT-S4 and FPT-S-5) were determined to contain ample groundwater to serve as monitoring wells for the area (Figure 2-2). The wells were installed during the fall of 2001 and sampled in May 2002. The Floodplain Tailings monitoring wells were installed to gain an understanding of the water quality in the area west of Silver Creek and how this water is effecting the water quality of the adjacent reach of Silver Creek and the shallow groundwater aquifer. In addition, the groundwater elevation data collected from these wells was used to calculate the potentiometric surface for the reach of Silver Creek adjacent to this area.

The Floodplain Tailings monitoring wells were installed using a hand auger. Each well consists of a slotted 1" PVC interval with a sand-pack, a PVC riser and a clay surface seal. Each well was installed to the base of the tailings interval at the contact with an underlying black clay. The installation and sampling conducted in the Floodplain tailings area was not detailed in the SAP (RMC, 2001); however, sampling was conducted according to the protocols outlined for groundwater sampling in the SAP (RMC, 2001).



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### **2.3 Onsite Soils Cover Sampling**

At forty-one (41) locations, soil samples were collected on the tailings impoundment to determine: 1) the extent and thickness of the soil cover and 2) chemical characteristics of the surface soils. Sample locations are shown on Figure 2-4. Samples were collected at the surface (0-2") at each location to characterize the cover materials for potential human and ecological risks from exposure to the cover soils. All samples were analyzed for lead and arsenic and 20 percent of all surface samples collected were analyzed for RCRA metals (10 samples) plus copper and zinc. All samples were archived in the event that additional analyses are required.

The thickness of the soil cover was determined by excavating either by hand or backhoe down to the soil/tailings interface. The interface was visually verified at each location; the tailings are a characteristic gray color, sandy texture, while the soil cover is red-brown color and has a clayey texture. Eleven (11) samples were collected just above the cover/tailings interface and submitted for laboratory analyses to verify the visual method. The results of analytical sampling confirmed the verified visual inspection methods. The analytical results are presented in Section 4.4.

On-site soil sample locations are shown on Figure 2-4. Sample collection was conducted according to procedures in Section 3.2 of the SAP (RMC, 2001).

### **2.4 Offsite Soils Cover sampling**

At twenty-eight (28) locations, soil samples were collected along three transects, oriented perpendicular to the prevailing wind direction, to assess the extent and potential human health and/or environmental impacts from wind blown tailings. The prevailing wind direction is from the southeast as determined by EPA's contractor in the 1986 air sampling at Richardson Flat (E&E, 1987).

A wind rose from the EPA Air Sampling Report is presented as Figure 2-5. Samples were collected at 0-2" and 1-6" depth intervals along the transects indicated on Figure 2-6. Data from this sampling effort will be used in the risk assessment process to evaluate if there is a threat to human health or the environment from exposure to off-site soils.

Off-site soil sample locations are shown on Figure 2-6. Sample collection was conducted according to procedures described in Section 3.2 of the SAP (RMC, 2001).

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### **2.5 Sediment Sampling**

Sediment samples were collected at six (6) locations in the South Diversion Ditch. The sediment samples were used to evaluate the source of elevated zinc concentrations in water samples collected in 1999 and evaluate ecological risks. At each location a sample was collected at a depth of 0 to 6 inches. The samples were analyzed for RCRA metals plus zinc and copper. These samples were archived by the laboratory until it can be determined whether additional analysis is required.

All sediment sample locations are shown on Figure 2-7. Sample collection was conducted according to procedures in Section 3.2 of the SAP (RMC, 2001).

### **2.6 Tailings**

Samples of tailings were collected at three (3) locations within the impoundment from test-pits excavated with a backhoe. At each location, five (5) discrete samples were collected at one (1) foot vertical increments, starting from the bottom of the cover over the tailings down to a depth of five (5) feet below the ground surface. In addition, a composite sample prepared from a split of each increment was prepared and analyzed for acid/base potential to assess long-term geochemical characteristics of the tailings materials.

All test-pit locations are shown on Figure 2-7. Sample collection was conducted according to procedures outlined in Section 3.2 of the SAP (RMC, 2001).

To maximize visual observations of tailings, soils and the tailings/soils interface, as well as to maximize sample quantities a backhoe was used to dig test pits. The test pit enabled site personnel to view the soils/tailings interface in a three-dimensional view. This provided an understanding of the physical characteristics of the interface and provided information about the spatial configuration of the interface. Test pits were excavated with minimal disturbance and were not excavated below the current water table. Excavated soils were sorted and stockpiled adjacent to the test pit. Upon completion of sampling activities the test pits were backfilled. To prevent soil mixing, each soil horizon was backfilled with soils removed from that horizon. Soils were compacted with the bucket of the backhoe during backfilling.

### **2.7 Tailings South of the Diversion Ditch**

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The tailings outside of the impoundment have been covered with at least one and up to five feet of clean soil (See Section 4.2, Focused RI/FS Workplan, RMC, 2000). The actual limit and extent of the tailings south of the diversion ditch were identified using a combination of aerial photography review and investigative field methods. The approximate, pre-investigation limits of these tailings were marked with a dashed green line as the "tailings outside of the impoundment" on Figure 5.0 of the SAP (RMC, 2001). The results of this investigation provide a definitive model of the extent of the tailings located south of the diversion ditch and define study boundaries in that area. Subsurface samples were collected to determine: 1) the extent of tailings south of the South Diversion Ditch, 2) the thickness of soil cover on these tailings, 3) whether these tailings are contributing to elevated zinc levels in the diversion ditch and 4) to assess whether metals have migrated below the tailings and the underlying clay interface.

Subsurface samples were collected using a combination of shallow hand tool excavation, and backhoe test pits. A total of sixty three (63) backhoe test pits were excavated (Figure 2-8). In addition, a series of shallow hand excavations were dug in the southwestern portion of the Site. These hand dug excavations were completed to assess the cover thickness in the seasonally wet area of the Site. These two methods involved visual inspection of subsurface soils. To confirm the results of visual inspection, analytical samples were collected at 10 percent of the backhoe excavation locations (7 locations). The analytical soil samples were collected above and below any color or texture changes. The results of the sample analysis are presented in Section 4.7.

A review of historical aerial photographs was conducted to assess the outermost limits of the tailings south of the diversion ditch. The approximate location of tailings was determined from reviewing a series of historical aerial photographs. Where possible, the location of the tailings were determined by examining the photographs for discontinuities that may be indicative of the boundaries of the tailings and native ground. These discontinuities included changes in plant cover, drainage patterns and general geomorphology. The locations of the tailings/native ground boundary were compared to the locations of known points such as fencing and roads. The boundary was then staked on the ground using the known points as reference locations. The staked boundary locations acted as a starting point for the field delineation of the tailings/native ground boundary.

Three (3) monitoring wells , designated RT-13, RT-14 and RT-15, were installed in the tailings outside of the impoundment. The installation of these three monitoring wells was discussed in Section 2.2.2. The

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monitoring wells were installed in specific areas to further define the hydraulic gradient and groundwater chemistry within the tailings outside the diversion ditch.

Sample location and collection were conducted according to procedures in Section 3.2 of the SAP (RMC, 2001). Test pit and samples locations are presented in Figure 2-8.

### **2.8 Background Soil Sampling**

At eleven (11) locations, background soil samples were collected in areas that have not been affected by tailings deposition. The samples were used to determine baseline concentrations of metals in areas not affected by tailings deposition.

Discrete samples were collected at the surface (0-2") at each location and analyzed for lead and arsenic to characterize the background concentrations of metals in the area surrounding the tailings impoundment. In addition, two (2) samples were analyzed for RCRA metals plus copper and zinc.

Background soil sample locations are shown on Figure 2-9. Sample collection was conducted according to procedures in Section 3.2 of the SAP (RMC, 2001).

### **2.9 Study Area Boundary Sampling**

At nine (9) locations, samples were collected as an aid to determine the study area boundary.

Discrete samples were collected at the surface (0-2") at each location and analyzed for lead and arsenic to characterize the soils in the vicinity of the study area.

Study area boundary soil sample locations are shown on Figure 2-10. Sample collection was conducted according to procedures in Section 3.2 of the SAP (RMC, 2001).

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### **3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA**

This section describes the physical characteristics and the geologic setting of the Site and surrounding area.

#### **3.1 Physical Characteristics**

The physical characteristics of the Site presented in this report were determined by a combination of the field activities detailed in Section 2 of this report and a compilation of data from previous reports.

As discussed in Section 1.2.1, the entire Richardson Flat property covers approximately 700 acres in a small valley located in Summit County, Utah. The tailings impoundment covers approximately 160 acres in the northwest corner of the property and consists of a large geometrically closed basin formed by an embankment and a series of perimeter containment dikes. The Site boundary as determined by this study contains the tailings impoundment as well as adjacent areas impacted by historical use of the Site is presented in Figure 1-3. The Study Area Boundary determined by this study contains an area of approximately 263 acres.

##### **3.1.1 Surface Features**

The site is located at an elevation of approximately 6,600 feet above sea level and consists of a geometrically closed tailings impoundment surrounded by an earthen dam on the west side and two containment ditches on the north, south and east sides. The containment ditches flow into Silver Creek. The area surrounding the impoundment consists of valley bottom topography surrounded by rolling hills.

An old railroad grade passes through the site south of the South Diversion Ditch. The impoundment area is approximately bounded by Utah Highway 248 to the north, a rail trail (reclaimed railroad grade) to the west and the South Diversion Ditch to the south. These roads and grades are not containment features and have no bearing on the Site boundary as defined by the extents of contamination.

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### **3.1.2 Meteorology**

Long-term meteorological observations have not been kept at the Site. The two nearest meteorological data stations are located in Park City, Utah which is located 500 feet higher in elevation three miles to the southeast in the Wasatch Mountains, and Kamas, Utah located at a similar elevation to the Site and nine miles to the east. The annual precipitation rate for the Site likely falls in-between the values for the two sites. Annual precipitation at Park City is 21.44 inches of water with an annual average high temperature of 56.3 degrees and an annual average low temperature of 30.8 degrees. Annual precipitation at Kamas is 17.27 inches of water per year with an average annual low temperature of 29.0 degrees and an average annual high temperature of 58.7 degrees (www.wrc.dri.edu, 2001).

Long-term wind data have not been kept in the vicinity of the Site. The prevailing wind direction is from the northwest to southeast east as determined by the EPA contractor Ecology and Environment during an air monitoring assessment conducted in 1986 (Figure F8, E&E, 1987).

### **3.1.3 Surface Water Hydrology**

The surface water hydrology of the Site consists of two distinct but interconnected entities: the tailings impoundment and the Silver Creek watershed.

The tailings impoundment consists of a man-made geometrically enclosed basin. The impoundment is bounded to the north, south and east by containment ditches and to the west by an embankment. The embankment isolates the tailings from Silver Creek. Beneath the impoundment, a layer of clay soil provides a boundary to infiltration of impoundment water into the underlying aquifers (*See* Weston, 1999; MWH, 2002). Surface water may occur on the impoundment during winter, spring and a portion of the summer depending on the amount of precipitation occurring during the year. A substantial portion of the precipitation falling on the impoundment remains within the bounds of the impoundment until it evaporates (Weston, 1999).

Between the main embankment and Silver Creek is a wetland area where the diversion ditch meanders through the wetland and eventually joins Silver Creek near State Highway 248. The wetland area may possibly receive minor seepage from the main embankment. Beaver dams have blocked and slowed the flow of Silver Creek in this area.

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Surface water hydrology outside of the impoundment consists of Silver Creek and two ephemeral drainages located to the south and east of the impoundment. Surface water from the southern drainage enters a seasonal pond south of the county road and depending on the amount of precipitation that falls within the drainage, water may be present from spring to late summer. Surface water from the eastern drainage enters the Site in the vicinity of sample location RF-1. Surface water in the eastern drainage is typically limited to periods of spring runoff.

Surface water flows have been measured as part of monthly water sampling activities at the following locations: RF-2, RF-3-2, RF-4, RF-6-2 and RF7-2. Surface water chemistry data was collected at these and other locations during the investigation. Flow data for each location is presented in Table 3-1. Surface water data were collected for a sixteen (16) month period beginning April 2001. Seasonal variations are apparent in all of the locations sampled. The seasonal variations are consistent with the variations observed in the monitoring wells located in the Silver Creek alluvial aquifer and in the tailings south of the diversion ditch. In general, peak flows were observed during the month of May with a seasonal decline through the summer and early fall months. Flow in Silver Creek as measured at location RF-7-2 began to increase in October 2001. This increase is likely related to an increase in precipitation during the fall months. Flow increases were not observed in the South Diversion Ditch and the ephemeral drainages located upgradient from the impoundment during the fall period that increases were observed in Silver Creek. Flow did not increase in the South Diversion Ditch until the onset of the spring runoff cycle. The South Diversion Ditch remained frozen during the winter months, making flow measurements and sampling infeasible.

### **3.1.4 Groundwater Hydrogeology**

Geotechnical borings, small-diameter piezometers, monitoring wells, and groundwater exploration borings were used to characterize the stratigraphic units in and around the Site. Beginning at the surface the stratigraphic units are:

- Clay rich topsoil (hydraulic conductivity  $>10^{-7}$  cm/sec)
- Alluvium/colluvium derived from Silver Creek and attendant subsidiary drainages
- Tertiary sedimentary and Keetley Volcanic rocks
- Mesozoic and Paleozoic rocks

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The shallow aquifers near the tailings pond are composed of mixtures of silt, sand and gravel located along the Silver Creek drainage, and deeper gravelly clay and sand and gravels mixed with abundant fine-grained materials varying from approximately 50 feet in thickness in areas south of the tailings impoundment to approximately 20 feet thick beneath the impoundment. Approximately 500 to 1,000 feet of moderately hard and fractured volcaniclastic rocks composing the Tertiary sedimentary rocks and Keetley Volcanic rocks underlie the tailings impoundment. The volcanic rocks overly several thousand feet of shale, claystone, limestone, sandstone and quartzite comprising the Mesozoic and Paleozoic rocks which serve as the source of drinking water supplies for the Park City Municipal Corporation.

At least five groundwater systems are found in the Richardson Flats area. Groundwater stored in the impounded tailings is under unconfined conditions and is not in hydraulic connection with the deeper water bearing strata due to the lower permeability clay-rich topsoil underlying the tailings. The saturation of the shallow alluvium in the vicinity of the tailings impoundment varies with the seasons; when saturated it serves as a locally perched water table.

The deeper alluvium is composed of thin layers of saturated and confined sand and gravel mixed with abundant fine-grained materials which yield small quantities of water to the piezometers and monitoring wells. The hydraulic communication between the shallow and deeper water bearing intervals is poor. South of Richardson Flats, the hydraulic gradient between the shallow and deeper water is downward. The hydraulic gradient between the deeper and shallow aquifer reverses and is upward as groundwater flows northward towards the tailings impoundment, ultimately discharging into the diversion ditch and Silver Creek which serve as the local hydrologic sinks for the shallow aquifer system. Driller's logs and anecdotal reports by local drilling contractors indicates no wells develop water from the alluvium due to the low productivity of these unconsolidated aquifers. The only wells tapping the alluvium and colluvium overlying the Keetley Volcanics include the various piezometers and monitoring wells in the vicinity of the Site.

The underlying and adjacent fractured Keetley volcanic rocks yield low to moderate quantities of water and serve as the water supplies for industrial and public water supply wells and small springs. Twenty six wells and two springs were identified within the watershed near Richardson Flats, with the closest well located approximately one quarter mile downstream from the tailings impoundment. With the exception of the piezometers and monitoring wells, all wells are deeper than 150 feet and develop water stored in the Keetley and deeper aquifers. While the deeper fractured Mesozoic and Paleozoic rocks are developed



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by public water supply wells operated by the Park City Municipal Corporation, these wells are upgradient and located approximately two to three miles from Richardson Flats. Deep groundwater exploration wells drilled near Richardson Flats determined that volcanic clays within the Keetley Volcanic rocks serve as confining units between water bearing strata within the volcanic rocks and between the volcanic rocks and underlying Mesozoic and Paleozoic water bearing strata.

Flow in the shallow groundwater system mimics the local topography. Groundwater flow is generally from southwest to northeast towards the wetlands located south of the tailings impoundment.

Groundwater, beneath the clay rich topsoil moves from northeast to southwest and is eventually captured by the South Diversion Ditch. Water quality data from RT-7, a piezometer located in the wetlands, indicates that metal concentrations in the groundwater are well below screening criteria (see Section 4.0).

Groundwater stored in the tailings impoundment moves northwesterly towards the embankment under a relatively flat hydraulic gradient. The steep hydraulic gradient across the embankment indicates that the hydraulic conductivity of the embankment materials is less than the hydraulic conductivity of the tailings stored in the impoundment. Seepage rates across the embankment range from 0.6 to 63 gallons per day. Water budget calculations indicate that most if not all of the calculated seepage through the embankment is either lost by evaporation or consumed by the vegetation located at the toe of the embankment

A detailed report on the Hydrogeology of the Site was prepared under separate cover by Montgomery Watson Harza (Appendix 5).

### **3.1.5 Onsite Soils Cover**

The onsite soil cover within the impoundment area consists of imported low permeability clean soils. Construction sites throughout the Park City area and a borrow site between the northeast edge of the impoundment and Highway 248 were the sources of the onsite cover soils.

This investigation measured the thickness of cover soils on a 500 foot by 500 foot grid within, directly adjacent to and on the area immediately north of the impoundment. Onsite soils cover depths are presented in Figure 2-4 and listed in Table 3-2. The onsite soil cover thickness ranges from 6 inches to over 11 feet. The areas containing soil cover of less than one foot are generally located in the northern half of the impoundment area. The area containing the maximum soil cover is located in the south-central

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portion of the impoundment area. The distribution of soil cover is consistent with patterns of historical clean cover soil distribution on the Site and ground conditions during the initial placement of fill. Cover soils have been typically brought onto the Site using the entrance road located in the south-central portion of the Site. The area of the impoundment closest to the diversion ditch dried out first after tailings placement ceased allowing this area to be covered with clean fill first. Clean fill cover was progressively moved out towards the northern edge of the impoundment over time as the tailings dried and ground conditions allowed the use of heavy equipment.

Soil cover thickness south of the diversion ditch range from 7 inches to 1.5 feet. A clean soil stockpile is located south of the diversion ditch, containing approximately 100,000 cubic yards of clean soil imported from excavation sites in and around Park City. The soil cover thickness was not measured in this area. The present height of the stockpile is nearly 45 feet above the surrounding ground surface.

### **3.1.6 Offsite Soils Cover**

The soils observed during the offsite soils cover investigation consisted of a clay-rich, loamy topsoil. Tailings were encountered in three of the sample locations south of the impoundment (T2C, T2D, T3B, T3E). Sample locations are presented on Figure 2-6. In general the soils observed were typical of those found in the surrounding area as well as those observed while conducting background soil sampling (Section 3.1.10).

### **3.1.7 Sediment Sampling**

The six sediment samples collected from the South Diversion Ditch consisted of predominantly silty-clay/clayey-silts with some very fine to fine gravels and very fine to fine sands. The upper four to five inches of the sediment samples contained dense root material. This root material made the collection of a surface sample unfeasible. Sediment sample locations are presented in Figure 2-7.

### **3.1.8 Tailings**

The tailings observed consisted of two types of material: sandy tailings and clay slimes. The sandy tailings consisted of a gray, fine-grained sandy material with occasional very fine to fine grained metallic material, which is likely sulfide minerals. The tailings are generally non-cohesive and moderately well sorted. The clay slimes consist of a gray, cohesive, plastic clay. The clay slimes are interbedded with the

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sandy tailings. The clay slime horizons could not be correlated among the three test pits. The interface with the overlying soils cover is generally sharp and distinct. Tailings sample locations are presented in Figure 2-7.

### **3.1.9 Tailings South of the Diversion Ditch**

The physical characteristics of the tailings south of the diversion ditch are identical to the tailings observed within the impoundment area (Section 3.1.8). The observed thickness of the tailings ranged from 6 inches to 11.5 feet. The thickest area of tailings (GL-41 and GL-43) were observed in an area located adjacent to the old rail grade in the southeastern portion of the study area.

Tailings were observed in thirty-six (36) of the sixty-three (63) test pits excavated. The extent and thickness of the tailings are presented in Figure 2-8. Two of the test pits that contained tailings (GL-21 and GL-23) contained a mixture of tailings and soil. This area appears to have been disturbed. In twelve (12) of the locations that contained tailings, the tailings were not covered (Figure 3-1). The remaining twenty-four (24) locations contained a soil cover over the tailings (Figure 3-1). The soil cover varied from a brown, silty loamy topsoil to fill material. The interface between the tailings and the overlying soils is generally sharp and distinct.

The tailings south of the diversion ditch are underlain by a dark brown to black, cohesive, moderately plastic clay. The interface between the tailings and the underlying clay is sharp and distinct. The thickness of the clay was not evaluated. Evaluation of the thickness of the clay likely would have compromised the integrity of its confining properties.

Twenty-seven (27) locations did not contain tailings. These locations are primarily composed of a red-brown, clayey soil. These locations most likely represent upland areas that did not undergo tailings deposition.

The shape of the southern limits ("Green Line") of the tailings appears to have been affected by predepositional topography and the location of tailings input onto the site. Two tongues of tailings on the western portion of the area are likely present when tailings were emplaced. The eastern portion of the area contains two fan-like areas containing a shallow veneer (approximately one foot thick) of tailings.

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The two fans are laterally connected by a deeper (approximately 2.5 feet thick) lobe of tailings. These features may be related to pre-existing (e.g. pre-tailings deposition) topography.

### **3.1.10 Background Soil Sampling**

Soils at the eleven (11) background soil sample locations were generally composed of a red-brown to brown, silty, clayey, loamy, topsoil. At location BG-11, tailings were obviously encountered as shown by the metals concentrations from this location (Table 4-15). Background sample locations are presented in Figure 2-9.

### **3.1.11 Study Area Boundary Soil Sampling**

Soils at the eight (8) study area boundary soil sample locations contained soils generally composed of a red-brown to brown, silty, clayey, loamy topsoil. At location SAB-6, tailings were obviously encountered as indicated by the metals concentrations at this location. Study area boundary sample locations and concentrations are presented on Figure 2-10.

## **4.0 NATURE AND EXTENT OF CONTAMINATION**

This section describes the extent of contamination associated with the Site. The results of analytical testing detailed in this section are presented by medium: surface water, groundwater, onsite soils cover, offsite soils cover, sediment, tailings, tailings south of diversion ditch, background soils and study area boundary sampling. Ecological media such as vegetation, aquatic and terrestrial wildlife were not sampled as part of this investigation. United Park, EPA, and UDERR are presently addressing ecological media through a Screening Ecological Risk Assessment (SERA) and Biological Technical Assistance Group (BTAG) meetings. In early 2003 UNITED PARK will submit a SAP to EPA and UDERR to conduct ecological sampling on the Site in the Spring of 2003.

The concentrations of analytes are summarized in Tables 4-1 through 4-17. Analytical results are presented for data collected from April 2001 through August 2002. Monthly data collection activities have ceased as of August 2002. The surface water data set consists of sixteen (16) rounds of monthly sampling. The groundwater data set consists of fourteen (14) rounds of monthly sampling. The duration

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of both the surface and groundwater sampling periods exceed the twelve (12) month specified in the SAP (RMC, 2000).

Rather than present summary data for all metals evaluated during this study, the discussion in this section focuses on selected indicator metals. However, all data collected are presented in the attached tables. The discussion in this section focuses on arsenic and lead as marker contaminants for human health exposures. Generally, where lead and arsenic are elevated, then other heavy metals may be elevated as well. Metals such as cadmium, chromium (depending on valence state), mercury and selenium may present toxicity problems to ecological receptors. Zinc is used as a indicator contaminant in sediment, surface water and groundwater as it may pose a risk to aquatic organisms if it is dissolved in surface water, and the presence of zinc may indicate the presence of other metals. Zinc and cadmium are the contaminants of concern in the Silver Creek watershed. Based on data collected by UNITED PARK and others it appears that the zinc found in the Park City Mining District ores is soluble when exposed to water and oxygen. In most cases, these indicator metals represent the highest metals concentrations and likely greatest risk. From a risk management perspective managing indicator metal concentrations through remedial design will likely address other contaminants as well.

### **4.1 Surface Water**

The objectives of surface water sampling were to characterize seasonal water quality and quantity in the South Diversion Ditch and in unnamed drainages flowing into the diversion ditch and Silver Creek. A second objective was to provide additional surface water data for comparison with human health and ecological screening levels. Data from the unnamed drainages, which flow only in response to snowmelt or significant storm events, provide limited background water chemistry data. Table 4.1 presents the summary of surface water analytical data, Table 4.2 presents the low detection mercury data collected at select locations. The analytical data are used in Section 5.0 to evaluate fate and transport of Site contaminants.

All dissolved metal measurements were screened against Utah Water Quality Standards (*See*, Table 4-3). Silver Creek is classified by the State as Class 1C (protected for domestic purposes with prior treatment), 2B (protected for secondary contact recreation), and 3A (protected for cold water species of game fish and other aquatic life). The most stringent of these standards are generally the Class 3A aquatic wildlife chronic standards. For many metals such as cadmium and zinc, these wildlife standards are hardness

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dependent when determining the acute or chronic toxicity concentration of a metal. All appropriate parameters were adjusted for an average hardness measured at each sample location. The Laboratory Reporting Limit (LRL) for silver is 0.005 ppm the aquatic wildlife standard for silver is 0.0041 ppm. Most silver data for the diversion ditch are below the LRL. Assuming that one half of the LRL is an appropriate estimated concentration for non-detected values silver, it is likely that most silver concentrations measured in the diversion ditch are below the standard. Table 4-4 presents the limited data available for background water chemistry.

Surface water field parameters (pH, conductivity, temperature and flow) are presented in Table 3-1.

### **4.1.1 Background Water Quality**

Two locations were sampled in April and May 2001 and 2002 to collect background data. Sample locations RF-1 and RF-2 (Figure 2-1) are in the ephemeral drainage upstream from the impoundment. Complete analytical results are presented in Table 4-1. Flow in this drainage occurs only in response to snowmelt or large rainfall events. No flows occurred at these locations during sampling events later in the season. Data from these locations represent background surface water quality in the vicinity of the Site. Summary statistics for metals at these two locations are presented in Table 4-4.

As shown in Table 4-4, background concentrations for silver, cadmium, chromium and selenium are below laboratory reporting limits. Background total and dissolved arsenic concentrations range from <0.005 to 0.008 ppm. Background total mercury concentrations range from 0.00000198 to 0.00000693 ppm, while dissolved mercury concentrations range from 0.00000442 to 0.0002 ppm. Mercury was analyzed using two EPA Methods, 6010 and Method 1631 which measures to a parts per trillion resolution. Background total lead concentrations range from <0.005 to 0.005 ppm, while dissolved lead concentrations range from <0.005 to 0.007 ppm. Total antimony concentrations range from <0.005 to 0.006 ppm, while dissolved antimony concentrations range from <0.005 to 0.01 ppm. Background total zinc concentrations range from 0.022 to 0.094 ppm (average 0.048 ppm), while dissolved zinc concentrations range from 0.023 to 0.095 ppm (average 0.054 ppm). In a few instances dissolved exceeded total concentrations, this is likely due to sample collection or analytical errors. Sample collection at the background locations was difficult due to very low flows experienced during the June sampling period. The background sample locations are ephemeral drainages that flow only in response to

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snowmelt or high precipitation rainfall events. Other parameter statistics are presented in Table 4-4. Background pH ranges from 6.7 to 8.54 S.U. (Table 3-1).

### **4.1.2 South Diversion Ditch**

Surface water samples were collected from five (5) locations in the South Diversion Ditch (RF-4, RF-5, RF-6-2, RF-11 and RF-12) and one (1) location in a tributary to the diversion ditch (RF-3-2). The sampling locations are shown in Figure 2-1. Due to seasonal variations in flow, samples could not be collected from all four locations during each monthly sampling event. Sampling frequency for each station is presented in Table 2-1. Complete analytical results are presented in Table 4-1, low detect mercury data are presented in Table 4-2, and comparison of the data to Aquatic Wildlife Chronic Criteria (AWCC) is presented in Table 4-3. The South Diversion Ditch, part of the operating system for the tailings impoundment, collects snowmelt and stormwater run-on and intercepts groundwater flowing towards the impoundment from the south and west. Groundwater interception is inferred based on surface and groundwater elevation data collected from monitoring well RT-14 and staff gauge SG-1. In addition the lower section of the ditch functions as a wetland bioremediation system reducing metal concentrations in the water.

— WOW — didn't know we had one of these here

Table 4-3 presents a comparison of analytical results to the AWCC, the most stringent standards that may apply to the Site. Review of Table 4-3 indicates that zinc exceeds the criteria on the greatest frequency at location RF-4, with one sample exceeding the AWCC for zinc at RF-5. Zinc did not exceed the AWCC at RF6-2 located at the terminus of the diversion ditch. Low detection mercury analyses conducted at RF6-2 (terminus of the diversion ditch) indicated that mercury does not exceed the AWCC. Water quality at RF3-2 exceeded the AWCC for mercury one out of four rounds of sampling. Low detect mercury analyses were not conducted at this location, therefore, it is unknown if the water quality consistently exceeds the AWCC. At location RF-3-2, zinc measurements satisfied the AWCC except for one sample. In that sample, dissolved zinc was reported to be greater than total zinc, indicating either field or laboratory error. Samples collected at locations RF-11 and RF-12 in the upper reaches of the diversion ditch indicate an increase in zinc concentrations may be occurring in the reach located between the two sample locations. The samples collected at RF-11 are below the criteria while the samples collected at RF-12 exceeded the criteria. This may indicate an inflow of zinc impacted water in the reach between RF-11 and RF-12. Two possible sources of zinc in this area include a source in the ditch itself (such as sediments or tailings) or water that is emanating from the ponded area south of the county road (the area



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in the vicinity of SG-3 as shown on Figure 1-4). The ponded area commonly contains surface and sub-surface water during spring and early summer. The ponded area contains tailings that are at the surface or covered with a thin veneer of cover soils. Surface and shallow groundwater may interact with the tailings in this area and then flow at the surface or through the paleochannel (e.g. the pre-tailings channel) to be intercepted by the ditch.

The highest zinc concentrations are found at RF3-2, a tributary to the diversion ditch, while the lowest concentrations are found at RF6-2, where the diversion ditch enters the wetland. Time-series plots of dissolved zinc concentrations for each sample location except for RF-11 and RF-12 are provided on Figure 4-1. RF-11 and RF-12 are not included as they were added to the sampling program in 2002 and were only sampled two times. The time-series plots show that the peak zinc concentrations at RF3-2 were measured in June 2001, while peak concentrations at RF-4 and RF5 were measured in May 2001. Data collected at RF-4 and RF-5 during two spring runoff cycles indicate that zinc concentrations in the upper and middle reaches of the diversion ditch are proportional to flow rates. Although there is some variability in dissolved zinc concentrations at RF6-2 (0.023 to 0.15 ppm), no obvious seasonal effect is apparent. The dissolved zinc concentrations at RF6-2 were consistently less than about half of the AWCC.

### **4.1.3 Silver Creek**

Silver Creek surface waters were sampled at two (2) locations (Figure 2-1). Sample location RF7-2 is located upgradient from the impoundment. Sample location RF-8 is located downgradient from the impoundment. Complete analytical results are presented in Table 4-1.

Comparison of analytical results, presented in Table 4-1, to the AWCC indicate that only zinc (dissolved) exceeds the AWCC at the two Silver Creek surface water sample locations (*See*, Table 4-3). Time-series plots of dissolved zinc concentrations for each sample location are provided on Figure 4-1. The time-series plots show variability in dissolved zinc concentrations, with peak concentrations in May 2001 associated with spring runoff. Two additional peaks occur in late fall 2001 and early spring 2002.

### **4.1.4 Floodplain Tailings Area**

Surface water samples were sampled at five (5) locations to the west of Silver Creek in the vicinity of the Floodplain Tailings. Samples were collected in May 2002. Sample location PH-SW1 is located in the

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Pace Homer ditch near State Highway 224. Surface water sample FPT-SW1 was collected in Silver Creek upgradient from the Floodplain Tailings area, FPT-SW2 and FPT-SW-4 are located in the tailings area and FPT-SW3 is located downgradient from the tailings area. Complete analytical results are presented in Table 4-5.

Comparison of analytical results, presented in Table 4-6, to aquatic wildlife criteria indicate that dissolved zinc concentrations exceed the AWCC for zinc at two (2) locations FPT-SW1 and FPT-SW3.

### **4.1.5 Surface Water Summary**

The data presented in Sections 4.1.1 through 4.1.4 indicate that metals concentrations are substantially lower in water discharged from the South Diversion Ditch (RF6-2) than in Silver Creek (RF7-2 and RF8). In fact, zinc concentrations are two orders of magnitude lower at RF6-2 than in Silver Creek. Average dissolved zinc concentrations at RF6-2 were approximately 0.055 ppm during the investigation as compared to average dissolved zinc background concentrations measured at RF-1 and RF-2 of 0.033 ppm. Zinc concentrations in Silver Creek exceed zinc concentrations collected in surface water west of the Floodplain Tailings.

Surface waters in both upstream and downstream locations in Silver Creek contain zinc concentrations that exceed the chronic and acute aquatic wildlife standard for zinc. This is in contrast to the metals concentrations measured in the downstream end of the diversion ditch (RF6-2) that are below both the chronic and acute aquatic wildlife standard for zinc.

## **4.2 Ground Water**

The objectives of groundwater sampling were to determine metal concentrations in the Silver Creek shallow alluvial aquifer both up and downgradient of the impoundment as well as to assess groundwater conditions in the shallow aquifer associated with tailings south of the diversion ditch. Due to turbidity problems, the first round of samples collected in June were discarded (see Data Quality Assessment, RMC, 2002). Sample locations are presented in Figure 4-2. Complete analytical results are presented in Table 4-7. Groundwater field parameters (pH, temperature and flow) are presented in Table 3-1.

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### **4.2.1 Silver Creek Alluvial Aquifer**

The shallow Silver Creek Alluvial Aquifer was sampled at two locations: Monitoring Well RT-11 located upgradient of the Site, and Monitoring Well RT-12 located downgradient of the Site. Comparison of water chemistry data from these wells to Primary and Secondary Drinking Water Standards (PDWS and SDWS) and Treatment Technology Requirement (TTR) for drinking water is presented in Table 4-8. Comparison to these standards is conservative the shallow Silver Creek Alluvial Aquifer is not used as a drinking water source near or on the Site (*See*, Section 3.1.4 at p.23). This comparison indicates that antimony and cadmium exceed the PDWS both upstream and downstream of the Site; however six (6) of the last seven (7) downstream samples collected were below the PDWS for antimony. Iron exceeds the SDWS downstream of the Site, manganese and zinc exceed the SDWS both up and down stream of the site. Lead exceeds the TTR up and downstream of the site, however five (5) of the last six (6) downstream samples collected were below the standard. Three (3) out of fourteen (14) mercury samples exceeded the PDWS downstream of the site.

Time-series plots of total lead and zinc concentrations for each sample location are provided on Figure 4-2. Although there is some variability in lead and zinc concentrations, time-series patterns for these metals are somewhat consistent in RT-11, while time-series patterns are less consistent in RT-12.

### **4.2.2 Groundwater in Tailings South of the Diversion Ditch**

Groundwater contained in the tailings south of the diversion ditch was sampled in three monitoring wells: RT-13, RT-14 and RT-15. Monitoring Well RT-15 did not contain water during most of the study except two (2) samples were collected from RT-15 in April and May of 2002. Table 4-8 presents a comparison of analytical results to groundwater standards. Review of Table 4-8 indicates that groundwater in MW-15 exceeded the PDWS for cadmium, antimony and zinc. The Secondary National Water Standard (SNWS) for manganese was exceeded in all three wells. MW-14 exceeded the SNWS for iron, and MW-15 exceeded the Secondary National Water Standard for aluminum and iron. All other metals are below the the PDWS and SNWS. The results indicate that the groundwater sampled from wells RT-13 and RT-14 generally contains low concentrations of metals. Arsenic and lead concentrations are below or near the lower laboratory reporting limits. Only one dissolved zinc measurement exceeded potentially applicable standards out of twenty-six samples from these two wells. As mentioned above some metal concentrations exceed standards in well RT-15, however, given the limited volume of water present at this location impacts to surrounding resources are unlikely.

Time-series plots of total lead and zinc concentrations for each sample location are provided on Figure 4-2. Although there is some variability in lead and zinc concentrations, no clear seasonal relationship are apparent.

#### **4.2.3 Floodplain Tailings**

Shallow groundwater contained in the Floodplain Tailings was sampled from six (6) monitoring wells. Analytical results are presented in Table 4-5. Comparison of water chemistry data from these wells to Primary and Secondary Drinking Water Standards (PDWS and SDWS) and Treatment Technology Requirement (TTR) for drinking water is presented in Table 4-6. Review of Table 4-6 Indicates that arsenic (two of six wells), cadmium (five of six wells), mercury (one of six wells) and antimony (all six wells) exceeds the PDWS in the Floodplain tailings area. Aluminum (four of six wells), iron (five of six wells), manganese (five of six wells) and zinc (four of six wells) exceed the SDWS in the Floodplain Tailings area. Lead exceeds the TTR in all six of the wells sampled.

A potentiometric surface map for the reach of Silver Creek adjacent to the Floodplain Tailings is presented in Figure 4-3. A series of hydrogeologic sections for this area are presented in Figure 4-4. Based on the potentiometric data presented in Figure 4-3 it appears likely that in the reach adjacent to the Floodplain Tailings Silver Creek is a gaining stream and is receiving water through the area of the Floodplain Tailings although no perceptual difference in flow appears to exist. Water yield from the shallow Floodplain monitoring wells was extremely low with most of the wells barely yielding enough water to collect a sample. The low groundwater yield could explain why there does not appear to be a increase in the Silver Creek flow in this area. Figure 4-4 presents the hydrogeology in the vicinity of Silver creek and the Floodplain Tailings schematically.

#### **4.2.4 Groundwater Results Summary**

Groundwater sampling results indicate that the groundwater contained within the tailings south of the diversion ditch has much lower concentrations of metals than the groundwater in the Silver Creek alluvial aquifer. Average dissolved zinc concentrations in groundwater associated with the tailings are about 500 times lower than concentrations measured in the upgradient Silver Creek alluvial aquifer. Based on these data, it does not appear that the Richardson Flat tailings are contributing zinc or other metals to the Silver Creek alluvial aquifer. Tailings south of the diversion ditch are contained by the native and imported clay

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soils, data collected by RMC and Weston show that the clay beneath the tailings is providing a barrier to the transport of metals in the tailings. In addition data from wells RT-12 and RT-13 indicate that very little leaching is occurring in those locations. This is due to the depth of clay fill (exceeding 1.0 feet) over the tailings in those areas. The data do show that leaching of metals is occurring near RT-15, however, the quantity of groundwater present in this area is low and is related to spring snowmelt. The depth of cover over tailings in the RT-15 area may be less than the area near RT-12 and RT-13. Data collected as part of the focused RI does not indicate that tailings in and around the impoundment are impacting Silver Creek alluvial wells. It does appear from water analyses and water elevation data that the Floodplain Tailings may be impacting Silver Creek water chemistry. In the area near RT-12 it appears that the groundwater is approximately four (4) feet lower than surface water in Silver Creek. Based on this elevation difference Silver Creek may be a losing stream near RT-12.

### **4.3 Onsite Soil Cover**

The objectives of the onsite soil cover investigation were to determine: (1) the extent and thickness of the soil cover and (2) the chemical characteristics of the surface soils that have been previously placed to cover the Site. A 500 by 500-foot grid was used to locate forty-one (41) sample locations (Figure 4-5). All samples were analyzed for lead and arsenic. In addition twenty-four (24) samples were analyzed for the eight RCRA metals including zinc and copper. The thickness of the soil cover was measured at each sample location. Complete sample results are presented in Table 4-9.

Forty-one (41) samples were collected at the surface (0-2") to evaluate metals concentrations in the uppermost portion of the soil cover. In addition, eleven (11) samples were collected directly above the cover/tailings interface. These samples were collected to confirm the visual verification of the interface. The depth of the interface samples ranged from 6 to 18 inches.

Analytical results for the 58 samples (includes duplicate sample results) of onsite soil cover samples indicate a range of values from 13 to 3,239 ppm lead and <5 to 121 ppm for arsenic. The average lead concentration of the forty-one (41) samples collected from the 0 to 2-inch zone was 395 ppm. The average arsenic concentration of the forty-one (41) samples from the 0 to 2-inch zone was 22 ppm. As a means of comparison, utilizing information presented in the draft BHHRA site-specific, health based screening values for lead of 17, 186 and 8,593 ppm for low and high intensity, respectively, users were

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calculated.<sup>3</sup> This value range assumes the number of days spent on Site would range from 50 to 100 days. Comparing this value to the 0-2" Onsite Cover Soil data indicates that there are no unacceptable exposures to lead from the Onsite Cover soil. For arsenic, the exposure assumptions provided in the draft BHHRA can be used to derive a health-based screening soil concentration for arsenic. Using the HIF for soil/tailing ingestion and the assumed default relative bioavailability value of 0.8 from that report, the resulting screening values are 379 ppm for the low intensity user, and 641 ppm for the high intensity user. These values were derived based on soil ingestion exposure only, target cancer endpoints of toxicity, and assume a target risk level of  $1 \times 10^{-4}$ . Measure concentrations of arsenic in all transect samples from the on-site soils area fall below these screening values.

In the eleven (11) deeper samples, lead concentrations ranged from 13 to 634 ppm with an average of 110 ppm. Arsenic concentrations ranged from <5 to 46 ppm with an average of 12 ppm.

In addition to the lead and arsenic analysis, twenty-two (22) samples were analyzed for the eight RCRA metals as well as zinc and copper. Analytical results for these metals are presented in Table 4-9. There are no regulatory criteria for metals in soils as there are for metals in water. The sampling results will be compared to appropriate risk-based concentrations, or background soil concentrations as part of the ecological and human health risk assessments.

The distribution of lead concentrations in the onsite cover soils was analyzed by plotting the concentrations on a Site Map (Figure 4-5). The distribution of lead concentrations in the 0 to 2-inch interval of onsite cover soils appears to be fairly random most of the highest concentrations are along the western and southern sides of the tailings impoundment. This appears to be related to the thickness of soil cover in those areas, in a few of the areas sampled the cover thickness was less than six inches and some mixing appears to have occurred.

### **4.4 Offsite Soils Cover**

The objectives of the offsite cover sampling was to assess the extent and potential human health and and/or environmental impact from windblown tailings as well as to aid in the delineation of the study area boundary. Samples were collected from three (3) transects, orientated perpendicular to the prevailing wind directions. The prevailing wind direction, as determined by EPA's contractor (E&E, 1987), is from

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3. These values are draft and subject to update by EPA.

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the southeast (See, Figure 2-5). Samples were collected from 28 locations (Figure 2-4). One transect was located to the north of the Site (T1). Two transects were located to the south of the Site (T2 and T3).

Analytical results are presented in Table 4-10. The analytical results of the samples analyzed indicate a range of 17 to 5,875 ppm lead and 7.1 to 243 ppm arsenic for the 28 samples collected from 0 to 2 inches. The samples collected from the 1 to 6-inch interval contained a range of 18 to 6,265 ppm lead and 6 to 316 ppm arsenic. The arsenic/lead ratio is similar in samples with both high and low metals concentrations (i.e., an increase in lead values correlates to an increase in arsenic values).

The average results for each transect are presented below:

<u>Transect</u>	<u>0-2" Pb</u>	<u>0-2" As</u>	<u>1-6" Pb</u>	<u>1-6" As</u>
Transect 1	123 ppm	12 ppm	108 ppm	11 ppm
Transect 2	1,636 ppm	74 ppm	1,446 ppm	75 ppm
Transect 3	142 ppm	12 ppm	86 ppm	10 ppm

The results of individual transects indicate that the lead and arsenic concentrations contained in Transect 2 are significantly greater than in samples from Transects 1 and 3. Transect 2 is located to the south of the impoundment area with portions of the transect located within the area containing tailings south of the diversion ditch. It is possible that at certain locations on Transect 2 the tailings may not be completely covered. The area containing the highest lead and arsenic concentrations (T2 C, D and E) has areas of exposed tailings.

The average lead concentration data indicate that Transects T1 and T3 are not impacted by wind blown tailings. Comparison of individual data points with a background lead concentration of 114 ppm (Letter to EPA RMC, 2/11/02) indicates that a few locations (T1A and T3B, Table 4-10) may have been impacted by wind blown tailings. Lead concentrations in these transect samples (both surface and subsurface) fall below a site-specific, health based screening value that can be derived from the May 2002 draft BHHRA for recreational visitors at the Site. Specifically, the input values for assessing adult exposures to lead that are described in the draft assessment were used to calculate health-based screening values for lead of 17,876 ppm and 8,593 ppm for low and high intensity users, respectively. As mentioned in Section 4.3 screening values determined for arsenic indicate that off-site soil concentrations

## **DRAFT**

measured on the three transects do not exceed the target risk level. These values do not incorporate any updates to the draft assessment that EPA may conduct.

In addition to the lead and arsenic analysis, five (5) samples were analyzed for the eight RCRA metals and zinc and copper. The results from the five samples do not indicate the presence of elevated concentrations of these metals in the offsite cover soils as compared to the results of background soil sampling (Section 4.8).

### **4.5 Sediment Sampling**

Sediment samples were collected from six (6) locations in the South Diversion Ditch (see Figure 2-7). Samples were collected from the 0 to 6-inch interval. The upper four to five inches of the sediment samples contained dense root material. This root material made the collection of a surface sample (0 to 2 inches) impossible. Complete analytical results are presented in Table 4-11.

Elevated concentrations of lead, arsenic and zinc were measured in all of the sediment samples. The analytical results for the six samples analyzed indicate a range of lead concentrations from 1,880 to 3,490 ppm, the average lead concentration is 2,578 ppm. The range for arsenic concentrations for the six samples is 101 to 205 ppm, the average arsenic concentration is 138 ppm. The range of zinc values for the six samples is 2,940 to 12,000 ppm, the average zinc value is 7,878 ppm.

The highest lead concentration was observed at the SD-1 location, this sample also contained the highest silver, cadmium, copper, iron, mercury and zinc concentrations. Location SD-1 is located in the lower most portion of the diversion ditch (See Figure 2.7). Arsenic, lead and zinc concentrations are lowest in the sample collected at the most upstream location (SD-6) of the ditch. The concentrations of these three metals is roughly proportional in the six samples collected. The distribution of metals in sediments along the diversion ditch is further discussed in Section 5.0.

X-ray Diffraction (XRD) analysis was performed on the six sediment samples from the South Diversion ditch. The results of the analysis indicate that the samples are predominantly composed of 30 to 45 percent quartz, 5 to 20 percent calcite, 10 to 15 percent dolomite, with smaller concentrations of the sulfide minerals pyrite (<5%) and sphalerite (<5%). Other minerals that may be present include: albite,





2



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anorthite, paragonite, montronite, clinochlore, ferro-gedrite and montmorillonite. These minerals contain a low level of crystallinity and are difficult to quantify using XRD analysis.

### **4.6 Tailings**

Tailings samples were collected from three backhoe excavated test pits located within the impoundment area (Figure 2-7). Six (6) samples were collected from each test pit. Samples were collected at one-foot intervals beginning at one foot below the soil cover/tailings interface. The soil cover was one-foot thick at each test pit location. Complete analytical results are presented in Table 4-12.

As expected, high concentrations of lead, arsenic and zinc were measured in the tailings samples. The range of lead values from the samples analyzed was 1,470 to 14,700 ppm with an average concentration of 4,530 ppm. The range of arsenic values in the samples analyzed was 148 to 417 ppm with an average of 254 ppm. The range of zinc values from the samples analyzed was 2,110 to 15,300 ppm with an average of 5,992 ppm.

Soil pH was analyzed for each of the three composite tailings samples collected (Table 4-13). The range of soil pH for the composite tailings samples was 7.3 to 7.7. The average pH value for the composite tailings samples was 7.5.

X-ray Diffraction (XRD) analysis was performed on the three composite tailings samples. The results of the analysis indicate that the samples are predominantly composed of 25 to 50 percent quartz, 5 to 40 percent calcite, 5 to 25 percent dolomite with the sulfide mineral pyrite (<5%) and ankerite (one sample, <5%). Minerals that may be present include: clinochlore, tosudite, galena, brushite, carlosturanite, ferro-gedrite and iron oxide. These minerals contain a low level of crystallinity and are difficult to quantify.

### **4.7 Tailings South of the Diversion Ditch**

Samples collected from the area south of the diversion ditch containing tailings were analyzed from a total of seven (7) sample locations (GL-50, GI-52, GI-53, GL-56, GI-58, GL-59, GL-62). The sample locations are shown in Figure 2-8. Two (2) samples were analyzed from each location. One sample was collected from the tailings located directly above the tailings/clay interface. A second sample from the clay was analyzed from directly below the tailings/clay interface. All samples were analyzed to confirm the visual

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assessment of the interface as well as to assess concentrations of metals above and below the interface.

Analytical results are presented in Table 4-14.

The average lead concentration in the tailings above the interface in the seven samples analyzed is 10,434 ppm. The average concentration of lead in the clay below the interface is 52 ppm, well below 114 ppm, the upper-bound background soil lead concentration (Letter to Jim Christiansen, RMC, 2/11/02). The average arsenic concentration in the tailings above the interface in the seven samples analyzed is 412 ppm. The average concentration of arsenic in the clay below the boundary is 9 ppm, well below 17.4 ppm, the upper-bound background soil arsenic concentration (Letter to Jim Christiansen, RMC, 2/11/02).

In general, the tailings metals concentrations are higher in the samples collected south of the diversion ditch than those of the samples collected from the three tailings test pits located within the impoundment (Section 4.6). The average lead concentration for the samples collected within the impoundment is 4,530 ppm as compared to 10,434 ppm for the samples collected south of the diversion ditch. The average arsenic concentration for the samples collected within the impoundment is 254 ppm as compared to 412 ppm for the samples collected south of the diversion ditch.

The average zinc concentration in the tailings above the interface in the seven samples analyzed is 11,355 ppm. The average concentration of zinc in the clay below the boundary is 349 ppm.

The difference in concentrations of metals in the tailings above the interface and the clay below the interface indicate distinct differences in the chemical composition of the two media. The difference also indicates that the downward migration of metals to the clay has not occurred and verifies the visual method employed to distinguish between the layers. Given the significant amount of time these tailings have been located in this area, it is unlikely that any significant downward migration of metals will occur in the future.

The average aluminum concentration in the tailings above the interface in the seven samples analyzed is 4,613 ppm. The average concentration of aluminum in the clay below the boundary is 24,594 ppm. The difference in aluminum concentrations can be attributed to the fact that the tailings and clay are composed of two separate materials. The aluminum concentrations in the clay can be attributed to the presence of clay minerals in which aluminum is the primary metal (Grim, 1968). Clay minerals are essentially hydrous aluminum silicates (Hurlbut and Klein, 1977) and naturally contain significant amounts of

## **DRAFT**

aluminum. X-ray diffraction analysis performed by Weston Engineering (1999) on soils underlying the tailings confirms the presence of sepiolite or mixed layer clay minerals (mixed mica and illite or smectite) in the material underlying the tailings. Mixed layer minerals typically adsorb water (Grim, 1968). Likewise, because of the weak bond between layers, metals are absorbed by the mixed-layered clays (Weston, 1999). As shown in Weston's report, (*See, Appendix 1*) Plate 1 the clay layer is continuous throughout all areas where tailings were deposited.

X-ray Diffraction (XRD) analysis was performed on three clay samples (Weston, 1999). The samples were analyzed for general minerals and also specifically for clays. The results of the general mineral analysis indicate that the samples are predominantly composed of 22 to 37 percent quartz. Other minerals that may be present include: clinochlore, albite, sanidine, muscovite, orthoclase and montmorillonite. The clay-specific analysis results indicate that the samples contained the following clays: montmorillonite, illite and dickite. The clay minerals contained low levels of crystallinity indicative of mixed layer clays (Grim, 1968).

Soil pH was analyzed for three of the clay samples collected (Table 4-13). The range of soil pH for the clay was 7.0 to 7.6. The average pH value for the clay samples was 7.2.

In summary, based on the analysis of the tailings and the underlying clays, it appears that metals contained in the tailings have not migrated into or through the clays. Migration of metals from the tailings into the underlying clay has not occurred south of the diversion ditch as shown by the tailings and clay metals analyses then it is unlikely that metals have leached from tailings in the impoundment and affected offsite resources.

### **4.8 Background Soil Sampling**

Soil samples were collected at eleven (11) locations to determine background metals concentrations in soils near the Site. The data obtained from the background samples was also used to define the Site limits. Samples were collected from locations shown on Figure 2-9. Analytical results are presented in Table 4-15. Table 4-16 presents a comparison of background sampling results with results obtained from onsite and offsite sampling for the full suite of metals (Ag, As, Ba, Cd, Cr, Cu, Hg, Pb and Zn). This comparison was conducted to fill in data gaps identified in the Screening Ecological Risk Assessment (Syracuse, 2002). Soil data presented in Table 4-16 represent background metal concentrations in that the

## ***DRAFT***

soil samples are either from native soil locations (e.g., transects) or of imported soil that came from surrounding sites in the area to provide cover for the tailings. As can be seen by the comparison metal concentrations in background (BG identifier) fall within the mean, plus or minus the standard deviation, of metal concentrations for either the cover or transect samples.

One sample collected was not indicative of background conditions. The lead concentration at BG-11 (7,731 ppm) is more indicative of metals impacted areas. Sample location BG-11 is located approximately one mile north of the Site in the floodplain of Silver Creek. Sample BG-11 was not used in background ranges or in calculating the average values.

The average lead concentration for the area surrounding the Site is 43.3 ppm. The average concentration for arsenic for the area surrounding the Site is 9 ppm. Two background samples were also analyzed for the eight RCRA metals. Elevated concentrations of the metals analyzed were not present in either of the samples analyzed.

### **4.9 Study Area Boundary Sampling**

The study area boundary was determined by utilizing off-site soils data and collecting an additional eight (8) samples. Samples were collected from locations where data gaps prevented the definition of a study area boundary. Study area boundary soil sample locations are presented on Figure 2-10. Study area boundary analytical results are presented in Table 4-17.

The Study Area Boundary was evaluated using data collected as part of the RI/FS investigation. The boundary was delineated using background soil lead concentrations and by circumscribing a line within those soil concentrations. This line represents the point at which background soil concentrations generally begin with lead being used as an indicator contaminant. The data indicate that if lead concentrations are elevated then other related metal concentrations are elevated as well. Table 4-17 portrays background soil lead concentrations and statistics used to estimate a mean background lead concentration for this area. A realistic estimate for the upper bound of the background soil lead concentration is the mean + the standard deviation. This results in a background soil lead concentration of 114 mg/kg. The area enclosed by the study area boundary contains approximately 263 acres.

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Because sample results indicate SAB-6 was located in an impacted area, the results from SAB-6 were not included in the data set used to calculate the upper-bound background concentration.

## **5.0 CONTAMINANT FATE AND TRANSPORT**

### **5.1 Introduction**

This section presents a discussion of the fate and transport of contaminants at Richardson Flat. Data and observations of source characteristics (e.g., tailings), site physical characteristics (e.g., hydrogeology, soil cover conditions) and the nature and extent of the contamination have been combined to develop an interpretation of the fate and transport of chemical constituents at the Site.

Because of the Site's complexities, it may not be practical to completely evaluate the fate and transport of contaminants using quantitative methods. A combination of semi-quantitative and qualitative methods will be used to develop as definitive as possible understanding of the fate and transport of contaminants at the Site. Several considerations can be raised regarding fate and transport based on the data presented in this study. These considerations include:

- What surface and subsurface processes are occurring at the Site, and how do they affect chemical constituents fate and transport?
- How do the characteristics and properties of the tailings and the local and regional hydrogeologic/geochemical system affect the distribution and migration of chemical constituents?
- What is the potential for chemical constituents generation from the tailings and potential for migration of contaminants offsite?
- What is the long term stability of the tailings and how will this affect long term use of the Site?

A site conceptual model has been developed based on the physical site characteristics presented in Section 3 and the nature and extent of contamination presented in Section 4. This conceptual model is graphically presented in two ways, as a three-dimensional block diagram (*See Appendix 5, MWH, 2002*) and as a schematic diagram showing connections between sources and the various potentially impacted media (Figure 5-1). These diagrams will serve as the basis for much of the discussion in this section.

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The remainder of this section is subdivided into four subsections: Sources and Primary Contaminants of Concern; Contaminant Characteristics and Transport Parameters; Potential Routes of Migration; and Contaminant Persistence and Source Stability. Section 5.2, presents Sources and Primary Contaminants of Concern, our understanding of the nature of the tailings and the primary contaminants of concern associated with the tailings. In Section 5.3, Contaminant Characteristics and Transport Parameters, the chemical and physical properties of the contaminants are discussed in order to develop an understanding of the processes likely controlling the fate and transport of contaminants at the Site. In Section 5.4, Release Mechanisms and Potential Routes of Migration, the potential and apparent pathways of contaminant migration between the various media at the Site are discussed. Evidence for the absence of a pathway is also evaluated. In Section 5.5, Contaminant Persistence and Source Stability, the physical and chemical parameters that control the persistence and stability of metals in the environment and the long-term stability of the metals within the tailings impoundment are discussed.

### **5.2 Sources and Primary Contaminants of Concern**

The source of metals at the Site is the historical placement of tailings from off-site mining operations. To better understand the potential for mobilization of metals, the source has been conceptually divided into two parts: (1) the tailings that are contained within the tailings impoundment where they are covered by a low permeability soil cover system consisting of a vegetated clay soil and contained within a containment dike system, and (2) the tailings that are mostly covered by a vegetated clay cap in small, naturally low areas outside and to the south of the impoundment.

#### **5.2.1 General Characteristics of Tailings**

The tailings are associated with historic ore processing. The tailings are composed of fine sand-sized granular material and clay-sized (<0.005 millimeters) slimes. The tailings impoundment can be visualized as a semi-rectangular shaped, geometrically closed basin, with a man-made main embankment on the west edge and perimeter containment dike system along the south and east sides and a sloping natural surface forming the fourth side (see 3-D block diagram in MWH, 2002). The main embankment is located along the western dimension of the impoundment. The tailings impoundment structure isolates and contains variably thick, slimy and sandy mill tailings materials. The impoundment is covered with a low permeability high clay-content, vegetated soil. The tailings have been constructed on naturally occurring thick layers of native, clay-rich soils (Geological Barrier).

## **DRAFT**

The clay-rich soils underlying the impoundment formed the original ground surface topsoil materials that existed at the Site prior to the deposition of the tailings. Permeability data reported by Weston (1999) indicate that these underlying clay soils have a low hydraulic conductivity, ranging from 0.001 to 5 ft/year ( $9 \times 10^{-10}$  to  $5 \times 10^{-6}$  cm/sec). However, closer review of the Weston report and Dames and Moore (1973) indicates that the hydraulic conductivity of 5 ft/year ( $5 \times 10^{-6}$  cm/sec) was reported for test pit TP-8 and the log for this test pit indicates that 4.5 feet of tailings overlie the 2.0 feet of silty soils. Therefore, the upper range of hydraulic conductivity of 5 ft/year ( $5 \times 10^{-6}$  cm/sec) reported for natural clay soils at Richardson Flat is skewed by the presence of tailings in TP-8. The clay soil cover on the tailings impoundment, for the most part, came from the same kinds of soils as found beneath the impoundment. The clay soil cover materials have hydraulic conductivity's ranging from 0.031 to 0.072 ft/year ( $3 \times 10^{-8}$  to  $7 \times 10^{-8}$  cm/sec) (Weston, Table 1, page 7, 1999). The hydraulic conductivity of the natural clay soil surface beneath the impoundment likely ranges from 0.001 to 0.072 ft/year ( $9 \times 10^{-10}$  to  $7 \times 10^{-8}$  cm/sec). It should be noted that EPA RARC Guidance documents specify soil liners of exhibiting  $1 \times 10^{-7}$  cm/sec permeability for use in disposal facilities. The Richardson Flats Tailings impoundment is constructed over a naturally occurring clay layer meeting and exceeding this EPA guidance requirement for liner system for RCRA landfills.

A diversion ditch system prevents most storm water from entering the impoundment from offsite sources.

### **5.2.2 Chemical Characteristics of Tailings**

The chemistry of the tailings is summarized in Table 5-1, which shows the range and average of metals data collected during this study. This table also presents data from the *Analytical Results Report – Richardson Flats Tailings* (E&E, 1985) and the *Final Report – Richardson Flats Tailings* (E&E, 1993) for comparative analysis and to provide additional analytical data for metals constituents not analyzed during this study. Data collected during this study are generally consistent with past analytical results from tailings samples.

### **5.2.3 Mineralogy of Tailings**

XRD analysis was conducted to determine the tailings mineralogy. The XRD test results indicate that the tailings typically consist of normal rock forming minerals (quartz, calcite, dolomite), sulfide ore minerals (pyrite, galena), and small fractions of hydroxides (tosudite, brushite, carlosturanite), and mica (clinochlore). These results are summarized in Table 5-2. Although the major portion of the tailings is quartz (25 to 50 percent), carbonate minerals calcite (5 to 40 percent) and dolomite (5 to 25 percent);



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sulfide minerals contain most of the metals of concern. Although galena (PbS) and pyrite (FeS<sub>2</sub>) were identified, no zinc sulfide minerals such as sphalerite (ZnS) were identified in the three composite samples tested. The high percentage of carbonate minerals provides substantial neutralizing buffering capacity, maintaining the tailings at near neutral pH conditions which limits the solubility of most metals. As reported in Section 4.6, pH ranged from 7.3 S.U. (Standard Unit) to 7.7 S.U. in the tailings samples.

### **5.2.4 Leaching Characteristics of Tailings**

The leaching characteristics of the tailings were evaluated using two laboratory testing methods: (1) the synthetic precipitation leaching procedure (SPLP), EPA SW-846 Method 1312, and (2) the acid-base potential test (USDA Handbook 60 Method 23C; EPA Method 670/2-74-070; EPA Method 600/2-78/084 Modified Sobek). Three composite tailings samples plus one duplicate sample were tested with these methods. The extraction fluid for the SPLP is an aqueous solution intended to simulate rain water prepared with deionized water buffered to a pH of 5.0 S.U. with sulfuric and nitric acids. The SPLP was developed to evaluate the fate and transport of metals in an engineered land disposal facility. The acid-base potential test measures the percentage of lime, the acid producing potential and the neutralization capacity of materials. The results also provide a percent breakdown of sulfur into non-sulfate sulfur, hot water extractable sulfur, hydrochloric acid extractable sulfur, nitric acid extractable sulfur and residual sulfur. The acid extractable sulfur fractions are often termed acid volatile sulfides.

As shown on Table 5-3, the SPLP results indicate that if the tailings were directly leached by the mildly acidic synthetic (rainwater) as used in the test, metals constituents such as cadmium, copper, lead, antimony and zinc would mobilize from the tailings. As the data indicate, zinc and lead would be the most leachable metals. This test indicates that the leachate would contain between 47 and 65 ppm zinc and between 10 and 13 ppm lead. The leachate could also contain up to 0.55 ppm cadmium. No silver, arsenic, chromium, iron, mercury, or selenium was mobilized during these tests. Although the SPLP results indicate that some metals can be leached from the tailings, the fact that metals levels in surface water and groundwater at the Site are not observed at concentrations of the same order-of-magnitude as the SPLP values indicates that the tailings are physically and hydraulically isolated and/or that there is sufficient buffering capacity in surficial soils, tailings carbonates and cover materials to rapidly buffer any acidity in local precipitation. Therefore, the SPLP does not provide the most appropriate data to assess the true leachability of the tailings in their present setting.

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As shown in Table 5-4, the acid-base potential results for the three tailings samples and one duplicate indicate that the acid potential of the tailings is between 112 and 181 tons  $\text{CaCO}_3$ /1000 tons of tailings in the form of water and acid extractable sulfur between 3.68 and 8.53 percent. However, the neutralization potential is between 198 and 271 tons  $\text{CaCO}_3$ /1000 tons tailings (19.8 to 27.1 percent lime) which indicates that there is a large excess base potential between 52 and 90 tons  $\text{CaCO}_3$ /1000 tons of tailings. Because most of the sulfur is in the form of acid volatile sulfides (leachable only under extremely acid conditions) and with abundant buffering capacity, the potential of the tailings to generate acidity which would allow metals to leach is extremely low.

### **5.3 Contaminant Characteristics and Transport Parameters**

#### **5.3.1 Metals Behavior and Relevant Fate and Transport Processes**

This section details the parameters that govern the fate and transport of metals at the Site. The fate and transport of metals is generally influenced by the following processes:

- Dissolution/Precipitation
- Oxidation/Reduction
- Complexation
- Adsorption and Coprecipitation
- Ion Exchange.

More specifically, the behavior of zinc, the primary contaminant of concern at the Site, is controlled by several processes including: the dissolution and precipitation of zinc-containing minerals; the formation of complexes with available anions; and the removal of zinc from solution by adsorption and coprecipitation. Although this section discusses the behavior of metals in general, it focuses on zinc which is the most mobile and widespread metal at the Site.

#### **Mineral Phases and Dissolution/Precipitation Reactions**

The dissolution of metals-containing minerals is the mechanism for exchanging metals from the solid phase to liquid phase. Although dissolution is often perceived as a one-way non-reversible reaction, metals can be re-precipitated in the original or as other mineral phases if geochemical conditions change. As discussed in Section 5.2, the tailings contain minerals, including sulfides, that can leach to the environment. Although galena ( $\text{PbS}$ ) and pyrite ( $\text{FeS}_2$ ) were the only sulfide minerals identified by XRD, it is probably safe to assume that some sphalerite ( $\text{ZnS}$ ) is present in the tailings. Sphalerite was the

## **DRAFT**

common zinc mineral encountered during mining of the ore body that produced the tailings (pers. comm. Kerry Gee, UNITED PARK, 2002).

The solubility of zinc is typically controlled by pH, Eh (redox) of the dissolving solutions and the presence and chemistry of zinc-containing solid phases, and the availability of other ions to create dissolved complexes. At the pH range observed in samples for this Site, typically 6.4 S.U. to 7.5 S.U.,  $\text{Zn}^{+2}$  is the predominant dissolved zinc species (Hem, 1972). At the near neutral pH conditions measured at the Site, a pH/Eh plot (Figure 5-2) by Hem (1972) indicates that  $\text{Zn}^{+2}$  is stable at Eh values above about -0.1 volts, mildly reducing to oxidizing conditions. Below this Eh, zinc sulfide is stable as a solid phase. Although not directly detected by XRD in the tailings samples, the presence of the mineral sphalerite (ZnS) likely plays a role in limiting the amount of zinc in solution. The presence of other zinc-containing sulfides, and zinc oxides, hydroxides, and carbonates may also play a role.

### **Reduction/Oxidation**

Reduction-oxidation (redox) reactions involve a change in the oxidation state of elements. The level of change is determined by the number of electrons on the element transferred during the reaction (Stumm and Morgan, 1981). Redox reactions can greatly affect contaminant transport (EPA, 1989). For example, in slightly acidic to alkaline environments, Fe (III) precipitates as a highly adsorptive solid phase (ferric hydroxide), whereas Fe(II) is very soluble and does not retain other metals. Although  $\text{Zn}^{+2}$  or Zn (II) is the stable valence state for zinc over a wide range of pH and Eh conditions, changes in the redox state of other ions may greatly affect the solubility of zinc. For example, changing the redox state of sulfur from S(+IV) to S(-II), sulfate to sulfide in the dissolved state, can cause the precipitation of zinc as the sulfide mineral sphalerite.

### **Complexation**

In a complexation reaction, a metal ion reacts with an ion that functions as a so-called ligand (EPA, 1989). The metal and the ligand bind together to form a new soluble species called a complex. Complexation can effectively increase the solubility of metals because the metals are mostly bound up in the soluble complexes (EPA, 1989).

The ability of zinc to form complexes with available major anions, particularly carbonate, sulfate and chloride, is an important factor affecting the solubility of zinc. Results of modeling using the USGS geochemical equilibrium program PHREEQC for waters in monitoring wells RT-11 and RT-12 indicate

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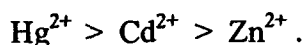
that about a third of the dissolved zinc exists as complexes with bicarbonate, carbonate, sulfate, chloride and hydroxide ions. The ability of the solution to create these dissolved complexes allows more zinc to be dissolved from available mineral phases than would be expected based on solubility constants, essentially increasing zinc solubility. The PHREEQC modeling also shows that the solutions at monitoring wells RT-11 and RT-12 are under-saturated with respect to sphalerite, smithsonite ( $\text{ZnCO}_3$ ) and  $\text{Zn(OH)}_2$ , suggesting that the solubility limit of zinc has not yet been reached (e.g. the water has the capacity to dissolve more zinc).

### **Adsorption and Coprecipitation**

Adsorption and coprecipitation can be important processes affecting the concentrations of metals in both solid and liquid phases. Adsorption occurs when a dissolved ion becomes attached to the surface of a pre-existing solid substrate (Drever, 1982). Coprecipitation occurs when a dissolved species is incorporated as a minor component in a solid phase as that phase itself is precipitated (Drever, 1982). Manganese and iron oxides often play important roles in both adsorption and coprecipitation reactions.

The likelihood of zinc adsorption depends on the adsorptive capacity of aquifer and/or streambank materials and the relative selectivity of zinc compared to other available cations. The surface adsorption of dissolved metal ions is a function of pH (Kekow, 2001). According to Kekow (2001) no zinc is adsorbed below a pH of 5 and all zinc is adsorbed above a pH of 8 (See Figure 5- 3). However, because of the relatively narrow range of pH observed at the Site, pH does not appear to be an important factor controlling the transport of zinc. Figure 5-3 also shows that lead and cadmium are fully adsorbed at even lower pH values than zinc, possibly explaining in part why lead and cadmium are more greatly attenuated than zinc.

The primary factors controlling selectivity are the charge of an ion and its ionic radius (Sposito, 1989). Compared to other available ions, zinc has a lower selectivity suggesting it would have a lower likelihood for adsorption. For example, Sposito (1989) worked out the following relative selectivity sequence for mercury, cadmium and zinc:



Based on zinc's relatively low selectivity and the abundance of other more preferable cations, zinc adsorption may not be an important factor affecting the zinc concentration in site waters. Solubility

## **DRAFT**

processes, as controlled by redox conditions and the relative abundance of dissolvable zinc minerals, more likely affect zinc concentrations in water.

### **Ion Exchange**

Ion-exchange reactions are similar in effect to adsorption, but unlike adsorption where ions are held in coordination bonding to specific two-dimensional surface sites, ion exchange sites are viewed as three-dimensional sites containing electrostatic forces. (EPA, 1989). Ion exchange best describes binding of metals and some anions to clays and condensed humic matter (Sposito, 1984). The capacity of a soil for cation exchange can be determined by displacing the exchangeable surface ions with ions in a standard solution that is brought in contact with the soil. Cation exchange capacity (CEC) tests were conducted on the six sediment samples from the South Diversion Ditch and three samples of "clay" underlying the tailings south of the diversion ditch. The results, provided in Table 5-5, indicate that the both the sediments and "clays" have substantial cation exchange capacities. The CEC values for the sediments range from 9.2 to 44.5 meq/100g, typical values for illite (Kekow, 2001). The CEC values for the "clays" range from 35.3 to 64.2 meq/100g, typical values for a mixture of illite and montmorillonite (Kekow, 2001).

### **5.4 Release Mechanisms and Potential Routes of Migration**

This section explains the fate and transport of chemical constituents within and between the media at the Site. The fate and transport of contaminants, particularly zinc, are evaluated and discussed in terms of the pathways shown on the schematic model of contaminant transport pathways (Figure 5-1).

#### **5.4.1 Leaching of Metals from Tailings Impoundment**

As described in Section 5.2, the tailings within the impoundment are deposited in well-contained layers, located between native clay materials below and a constructed low permeability vegetated clay soil cover above and surrounded by clay dikes. XRD data collected during this study confirm the findings of Weston (1999) that the underlying materials are predominantly composed of clay minerals, sepiolite or mixed layer clay minerals, mixed mica and illite or smectite. XRD analysis found that the samples contained primarily illite and dickite (a kaolinite group mineral with the same chemistry as kaolinite but with a slightly different structure), with one sample also containing montmorillonite. As discussed by Weston (1999) and MWH (2002), there is no hydraulic connection between the tailings and the upper aquifer. However, as shown on Figure 5-1, there are two potential release mechanisms for metals within the tailings impoundment: (1) leakage through the dikes into the South Diversion Ditch, and (2) observed

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seepage along the tailings embankment to the wetlands. If metals do leach from the tailings impoundment to the South Diversion Ditch they will likely be attenuated prior to discharge at the ditch terminus (See Section 4.1.2). This is evidenced by the low metals concentrations at RF6-2 which is located at the ditch terminus. Observed seepage from the tailings embankment does not contain sufficient volume to adversely impact the wetlands. A complete analysis of the mixing of water from the diversion ditch and seepage from the tailings embankment with Silver Creek is provided in Appendix C of the Work Plan (RMC, 1999).

### **5.4.2 Leaching of Metals from Tailings Outside Impoundment**

The tailings outside the impoundment sporadically contribute metals to the tailings aquifer and the South Diversion Ditch. Concentrations of zinc and other metals in monitoring wells RT-13, RT-14, and RT-15 (see Section 4.2.2) indicate that elevated zinc concentrations are measured in the tailings aquifer after tailings are inundated by spring snowmelt. For example, a dissolved zinc concentration of 4.3 mg/l was measured in May 2002, but dropped to 1.4 mg/l then 0.42 mg/l in June and July 2002. These elevated concentrations correspond directly with peak groundwater elevations at these wells. Another example of the relationship between zinc concentrations and groundwater levels is RT-15, which has been dry for several months. In April and May of 2002, 23 and 16 mg/l of dissolved zinc, respectively, were measured in RT-15. Figure 5-4 shows time-series plots of dissolved zinc concentrations in RT-13 and RT-14. Metals in the upper section of the diversion ditch are either coming from the tailings in the bottom of the ditch, are migrating seasonally from water within the tailings, or are related to the ponded area south of the Site, where tailings may be oxidized by storm water. The increase in zinc concentrations between locations RF-11 and RF-12 in the diversion ditch may be related to leaching from tailings in area that provides the source of inflows for that reach.

### **5.4.3 Transport of Metals from South Diversion Ditch to Wetlands**

Elevated metals concentrations have been measured in water and sediments within the South Diversion Ditch. The history of dissolved zinc concentrations at the six sample stations along the South Diversion Ditch are shown on Figure 5-5. With the exception of the very high spike at RF-3-2 in June 2001 (7.9 ppm), the general pattern is similar during each sampling round. Zinc concentrations are low in the upper reaches of the diversion ditch, but increase substantially between RF-3-2 (a tributary) and RF-4. This suggests a source of zinc and/or changes in geochemistry causing dissolution of zinc from sediments, an influx of zinc-containing groundwater between these two stations, or that ponded area is providing oxidized water and leaching zinc to the diversion ditch.

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Although zinc is the only metal at concentrations of concern in water, sediments within the ditch contain high levels of several metals including lead and zinc (Figure 5-6). Also shown in Figure 5-6, somewhat elevated concentrations of arsenic and cadmium have also been measured in sediments. Metals concentrations in the sediment increase from the beginning to the terminus of the diversion ditch with zinc and cadmium increasing by about 400 percent and lead and arsenic increasing by about 50 percent. The increase in metals may be attributable to several factors which may include:

- variability in reconstruction of the channel
- increasing percentage of tailings material via runoff or wind-blown processes
- biologically mediated precipitation of sulfide minerals
- adsorption on solids and organic material
- coprecipitation with other metals (such as manganese)
- cation exchange
- mechanical concentration (e.g. settling) of heavier materials
- variability in sediment sampling.

The presence of tailings in the sediments may be evaluated in two ways: (1) mineralogy by x-ray diffraction (XRD) patterns and (2) trace metal ratios.

A comparison of the mineralogy of tailings and sediment samples (Table 5-6) indicates that the bulk of the materials are composed of similar percentages of quartz, calcite, dolomite, pyrite, and clinocllore (a mica) suggesting a common source. However, the sediment sample lacks galena (PbS) which was found in all tailings samples, but contains sphalerite (ZnS) in all samples except the uppermost station SD-6. The sediment sample also lacked the hydroxides (tosudite, brushite, carlosturanite) and iron oxide reported in some of the tailings samples, but contained a wide assortment of other minerals including feldspars (albite, anorthite, sanidine, orthoclase), micas (paragonite, muscovite), clays (nontronite, montmorillonite), and an amphibole (ferro-gedrite). The sediments thus appear to be a mixture of biologically derived sulfide precipitates, tailings and imported soils. This combination of materials is due to past uses and reconstruction activities. In 1992 and 1993, United Park reconstructed the south diversion ditch by decreasing the slope of its banks from nearly vertical to a more gradual slope. United Park also placed a clay soil cover over the re-sloped banks of the south diversion ditch, down to and including areas of the banks underwater. The new banks were then seeded with appropriate varieties; presently, the existing ditch banks are vegetated. United Park did not disturb the bottom of the ditch bed.

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An evaluation of trace metal ratios indicates that although the sediments have generally lower metals concentrations than the tailings, the ratios of the important trace metals arsenic, cadmium, lead, and zinc are similar. In fact, the pie diagram for SD-6 and the average tailings are almost identical (see Figure 5-7). However, of note is that the average zinc concentration in the sediments is actually higher than the average tailings concentration suggesting that zinc is preferentially concentrated in the sediments by adsorption and precipitation processes (Table 5-6).

Considering the behavior of metals in water and sediments within the diversion ditch as a coupled system, a better understanding of the processes that are occurring emerges. For example, plotting the water results from 5/7/01 and the sediment results from 5/11/01 (Figure 5-8) together shows a generally inverse relationship between zinc concentrations in the water and solid phases. A similar relationship is observed for lead (Figure 5-9). Figure 5-10 provides plots of dissolved zinc versus other chemical parameters such as sulfate, TDS, bicarbonate, calcium, and manganese showing clear relationships between zinc and other chemical species. Between RF-2 and RF-4 major changes in water and sediment chemistry are occurring that strongly indicate a major inflow of poor quality, oxygenated water. In this reach, the concentrations of the following parameters increase sharply by the listed factors: TDS 2X, sulfate 10X, zinc 65X, manganese 92X, magnesium 3X, bicarbonate 2.5X, calcium 4X. RF3-2 is a tributary to this reach of the ditch the low concentrations are a "clean" water source draining into the ditch and is not experiencing similar concentration levels as RF-12. Field measurements of temperature and pH (Figure 5-11) also indicate that substantial mixing is occurring in this reach. The inflow into the ditch in this area is likely from cooler, lower pH, water, possibly from the ponded area south of the County Road.

Based on the similarity between the plots of dissolved zinc and manganese (see Figure 5-10e), it is possible that zinc may be coprecipitating with manganese or at least both metals are being attenuated by the same process. Cation exchange does not appear to be an important processes. In fact, the concentrations of zinc and cadmium in sediments along the ditch have a strong inverse relationship with cation exchange capacity (CEC) with a linear correlation coefficient of 0.93 for zinc and 0.86 for cadmium (Figure 5-12). In other words, as the (CEC) increases, the concentrations of these metals in ditch sediment decrease substantially. This suggests that cation exchange is not an important process.

The apparent attenuation of zinc and other metals in the diversion ditch appears to be at least biologically mediated by the diversion ditch wetlands. The coincident decrease in bicarbonate and calcium concentrations, rise in pH, and slight decrease in sulfate is consistent with the typical behavior of sulfate



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reducing bacteria in wetlands. Significant research by EPA, academia and industry has documented the effectiveness of wetlands to remove metals from water. Wetlands utilize naturally occurring biogeochemical processes to precipitate dissolved metals from solution and retain the resulting solid phase in the sediments of the wetland (Pantano, et.al. 1999). Although the subtle decline in sulfate concentrations which accompanies the dramatic drop in zinc concentrations does not at first glance appear to be significant, if we consider that the concentrations of zinc and other dissolved metals are more than two orders of magnitude lower (300X lower for zinc), then only a subtle decline of several parts-per-million in sulfate concentrations is required to precipitate all the zinc from solution.

Metals have also been found in sediments in the wetland below the main embankment (E&E, 1993). Samples RF-SE-01, RF-SE-02, RF-SE-03, and RF-SE-04 contain 3,010 to 6,520 ppm lead, 128 to 310 ppm arsenic, 40.3 to 75.6 ppm cadmium, and 5,400 to 15,200 ppm zinc. Although the origin of these metals is uncertain, they could be from Silver Creek tailings or impoundment tailings via the diversion ditch.

### **5.4.4 Migration of Metals from South Diversion Ditch and Wetlands to Silver Creek**

Metals concentrations measured in the South Diversion Ditch have declined markedly since the 1980's when the ditch was reconstructed and when the tailings were covered with clean soil. As stated in the Work Plan (RMC, 1999), data collected in 1999 and during this study indicate that zinc concentrations measured at the outfall of the ditch meet applicable water quality standards and are lower than zinc concentrations measured in Silver Creek. The downstream Silver Creek zinc concentrations are less than the upstream concentrations indicating that flow from the diversion ditch may be diluting the zinc concentrations in Silver Creek. A complete analysis of the mixing of water from the diversion ditch and seepage from the tailings embankment with Silver Creek is provided in Appendix C of the Work Plan (RMC, 1999).

### **5.4.5 Interaction of Wetlands with Silver Creek Alluvial Aquifer**

Although there is little groundwater data between the tailings impoundment and the vicinity of Silver Creek, the wetlands likely interact directly with the shallow part of the Silver Creek Alluvial Aquifer. Data from RT-7 indicates that there is little exchange of zinc and other metals between sediments in the wetlands and underlying shallow groundwater.

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### **5.4.6 Transport of Metals Between Upper Aquifer and Silver Creek Alluvial Aquifer**

Although some transport of zinc and other metals may occur between the upper aquifer and the Silver Creek alluvium, the groundwater chemistry of the Silver Creek alluvium does not appear to be noticeably influenced by the main body of Richardson Flat tailings. Although a small volume of groundwater may flow from the vicinity of the tailings impoundment toward Silver Creek, groundwater in the Silver Creek alluvium does not appear to be adversely impacted by the tailings or by surface water flowing in the South Diversion Ditch. Although groundwater in contact with tailings south of the South Diversion Ditch may seasonally contain elevated zinc concentrations, much of this groundwater is captured by the ditch. This is evidenced by the water level contour map presented in Appendix 5 (Figure 8, MWH 2002). This conclusion is supported by several lines of evidence including:

1. Groundwater originating in the vicinity of the tailings impoundment cannot be the source of elevated zinc concentrations observed in groundwater adjacent to Silver Creek because zinc concentrations are generally much lower near the tailings. Zinc concentrations, as measured in piezometer RT-7 (0.027 ppm on 2/27/01), in groundwater between the tailings impoundment and Silver Creek is substantially less than zinc concentrations measured in RT-11 and RT-12 which contains concentrations always greater than 4.8 ppm.
2. Surface water draining the tailings impoundment area cannot be the source of the elevated zinc concentrations observed in groundwater adjacent to Silver Creek. Although there have been some part-per-million concentrations measured in water from the South Diversion Ditch, these concentrations, when mixed with zinc concentrations at RT-11, do not result in the zinc concentrations measured in RT-12.
3. As shown in the Piper Plot for water samples collected during May 2002 (Figure 5-13), major ion data indicate that groundwater in the Silver Creek alluvium (RT-11, RT-12, RT-7) is similar to surface water in Silver Creek (RF-7-2 and RF-8) and the floodplain tailings indicating an intermingling of surface and ground-water along Silver Creek, while groundwater typical of the tailings impoundment area (RT-13 and RT-14) and surface water from the South Diversion Ditch (RF-6-2) generally plot as separate and distinct groups.
4. The concentration of total dissolved solids (TDS) in groundwater in the vicinity of the tailings (1,177 to 1,794 ppm in RT-13 and RT-14) and surface water in the South Diversion Ditch (644 to 2,110 ppm at RF6-2) is higher than the TDS in the Silver Creek Alluvium. In fact, TDS generally decreases from RT-11 (998 to 1,891 ppm, average 1,389 ppm) to RT-12 (754 to 2,095 ppm, average 1,112 ppm) suggesting dilution by lower TDS water, likely from Silver Creek (714 to 1,174 ppm, average 876 ppm at RF7-2). Mixing the higher TDS ground or surface water from the vicinity of the tailings with groundwater at RT-11 cannot result in groundwater with the lower TDS chemistry observed at RT-12.

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### **5.4.7 Interaction Between Silver Creek and Silver Creek Alluvial Aquifer**

Elevated concentrations of total and dissolved zinc are observed in groundwater within the Silver Creek alluvium. As shown in Figure 5-14, dissolved zinc concentrations range from 5.6 to 10 ppm in upgradient monitoring well RT-11 and from 6.4 to 22 ppm in downgradient monitoring well RT-12. As is apparent from the histogram of dissolved zinc concentrations, (Figure 5-15). The down-gradient zinc concentrations correspond to some of the highest zinc concentrations observed in surface and groundwater samples collected for the focused RI for the Site. Dissolved zinc concentrations of up to 85 mg/l were measured in Floodplain Tailings wells adjacent to Silver Creek. Other ranges of dissolved zinc concentrations in site waters include:

Groundwater (RT-13, RT-14)	<0.01 to 4.3* ppm
Groundwater (RT-15)	16 to 23 ppm (This well only contains water during spring)
Groundwater (RT-7)	0.027 ppm
Groundwater (RT-9)	0.021 ppm
Surface Water (South Diversion Ditch)	0.023 to 7.9* ppm
Surface Water (Silver Creek)	0.39 to 2.0 ppm

*\* Anomalous value possible laboratory or field error.*

The elevated zinc concentrations in groundwater adjacent to Silver Creek may be the result of several factors including: (1) dissolution of zinc from tailings and mine waste within the alluvium, Floodplain Tailings or within the Silver Creek embankments, (2) oxidizing conditions created by surface/groundwater exchange, and (3) ideal geochemical conditions for the dissolution of zinc-containing minerals (i.e., readily soluble minerals, available major anions for complexation, lack of available surface adsorption sites).

The increasing concentrations of zinc, in conjunction with generally decreasing TDS levels, between RT-11 and RT-12 should be noted. Although the concentrations in these two monitoring wells are not substantially different from a statistical standpoint, the increase may be caused by spatial heterogeneities in hydraulic conductivity (a function of grain size), adsorption potential, and sedimentation patterns. Hydraulic conductivity and groundwater flow rates are likely much higher near RT-11, where Silver Creek is flowing at a much higher rate than near RT-12 where it is partially dammed by the highway and beaver dams. Slower groundwater flow rates would allow for a longer residence time and increase the potential for zinc dissolution, however this is not consistent with the decrease in TDS. Variations in adsorption coefficients may be due to mineralogy (relative percentage of sulfides, feldspars, calcite), grain

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size and surface area of particles, and grain coatings (Davis and others, 1993). Sedimentation patterns may vary between RT-11 and RT-12 resulting in different relative masses of tailings and zinc-containing minerals. The increase in zinc concentrations between RT-11 and RT-12 may be the result of a combination of several factors including: (1) mixing with oxygen rich water from Silver Creek which would decrease the TDS concentration and increase zinc solubility, (2) an increase in residence time due to lower groundwater flow rates which would increase the time for zinc dissolution, and (3) possibly a slight increase in available zinc-containing minerals for dissolution.

Preliminary simulations with PHREEQC indicate that if even a small fraction of water from Silver Creek (RF-7-2), presumably in equilibrium with the atmosphere, is mixed with groundwater in the Silver Creek alluvium (RT-11) that is assumed to be in equilibrium with sphalerite, zinc concentrations will increase by a factor of 2 or more. This increase in zinc concentration results primarily from the change in redox conditions from the addition of oxygen-rich water from Silver Creek. This is consistent with data reported by Weston (1999) indicating that "Silver Creek is found at a higher elevation than groundwater stored in the shallow aquifer(s) located between the tailings embankment and Silver Creek." Figure 4-3, shows that Silver Creek at Rail Trail Bridge is about 4 feet higher than groundwater in RT-12. This difference in the potentiometric surface may be caused by variable gradients in different locations due to diffuse flow in the alluvial sediments. This same phenomena was also observed approximately one mile further downstream in the Silver Creek alluvium (Todd Jarvis, pers. comm. 2002). The increase in the relative difference between zinc concentrations in RT-11 and RT-12 in November and December 2001 suggests that Silver Creek may be losing more water in the winter than in the spring and summer. However, the dissolved zinc concentration of 22 mg/l measured in April 2002 suggests other possible sources of zinc such as the upper aquifer or the Floodplain Tailings. Coincidentally, 23 mg/l of dissolved zinc was measured in monitoring well RT-15 in April 2002, however this well is typically dry and only contains water during periods of high water during the spring runoff.

### **5.5 Contaminant Persistence and Source Stability**

This section discusses the persistence of the metals in the environment and the stability of the tailings (source) in their present state. As previously discussed, because of its solubility and mobility zinc is the primary contaminant of concern for water at the Site. Although other metals, including lead, arsenic, and cadmium, are measured in elevated concentrations in sediment in the South Diversion Ditch, dissolved concentrations of these metals in ground and surface water are generally low indicating they are stable in the solid phase and not mobile in the aqueous phase.

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Natural mechanisms that prevent acid formation and mobilization of metals from tailings are present in the tailings and the underlying soils and naturally occurring geologic materials. These mechanisms include:

- Predominant upward movement of water in the tailings due to evaporation exceeding precipitation rates
- Fine-grained nature of the tailings and cover that provides a physical barrier to percolation of water
- Geochemical properties of the tailings such as the presence of gangue minerals that limit the acid production and percolation of chemical constituents
- Geochemical and physical properties of the underlying soils that create a barrier to further migration of metals constituents from the site

For chemical constituents to mobilize from the tailings, metals from the tailings need to dissolve from the reactive minerals and move through the underlying tailings and soils to groundwater. This requires downward percolation of metals-bearing solutions. In the arid environment of the site, the dominant movement of water in tailings is upward, toward the tailings impoundment surface. Regional precipitation is much less than evapotranspiration (<http://climate.usu.edu>), so there is a net water loss from the upper portion of the tailings.

In an uncovered tailings impoundment upward movement of moisture through the tailings results in the formation of metal-sulfate salts that deposit on exposed surfaces of the tailings. Metals and sulfate are wicked to the tailings surface from oxidized pyrite and other forms of sulfides species. These salts are readily dissolved during rainfall. Typically, ponds may form on tailings during precipitation events and slowly evaporate, leaving crusts of metal-sulfate salts. If sufficient precipitation occurs, the salts will contribute metals and sulfate to the runoff water. Such is not the case at the Site, however as the tailings surface is covered with a high clay content soil ranging in thickness from approximately seven (7) inches to ten (10) feet. There are some locations on the Site where tailings are present on the surface and it is estimated that the surface area of these locations is less than 0.5% of the total site area.

The mobilization of metal constituents through site tailings is very limited due to fine grained tailing materials presented at the site and very low hydraulic conductivity measured in cover soils, tailings and underlying soils. Furthermore; the production of an oxidizing environment is inhibited by the lack of sufficient oxygen in the thick, low permeability tailings at Richardson Flats.

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### **5.5.1 Controls on Tailings Chemical Stability**

The chemical stability of the tailings is controlled by physical, hydraulic and geochemical factors. Physical factors include: underlying sorptive, low-permeability native materials; impoundment dykes and a vegetated clay-rich soil cover. Hydraulic controls consist of the soil cover that minimizes the infiltration of precipitation to the tailings and the diversion ditches that control runoff and runoff in the area. Chemical factors include the availability of abundant minerals to provide pH buffering capacity (i.e., the tailings contain 10 to 30 percent calcite and dolomite). The acid-base potential data indicates that an abundant amount of excess buffering capacity is available to neutralize any mildly acidic infiltration reaching the tailings. This buffering capacity is confirmed by XRD data indicating that the tailings contain between 25 and 45 percent of the carbonate minerals calcite and dolomite. The acid-base potential data also indicate that most of the sulfur is in the form of acid volatile sulfides that require much lower pH waters to leach metals than the mildly acidic precipitation that falls in this area. Clearly, the combination of almost infinite buffering capacity and physical and hydraulic controls maintain the metals in the tailings in a stable state. As long as the present physical and hydraulic controls are maintained, the tailings should remain chemically stable indefinitely.

### **5.5.2 Acid Generation Analysis**

Acid is generated in the tailings when metal sulfide minerals are oxidized. When metal sulfide minerals are present in the host rock, prior to mining, oxidation of these minerals will result in formation of sulfuric acid as a function of weathering processes. The oxidation of undisturbed ore bodies and acid generation and mobilization is very slow process.

Mining, extraction and beneficiation operations will increase the chemical reactions by exposing large volumes of sulfide rock material with an increased surface area to air and water. The potential for a mine waste to generate acid and release contaminants is a function of many factors and is site and waste specific. The acid generation and mobilization of constituents from a mine waste unit is a function of series a of factors that need to come together in a systematic manner, that can be divided into three groups:

#### **A) Primary Factors**

- a. Presence of sulfide minerals
- b. Water
- c. Oxygen
- d. Ferric iron

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- e. Bacteria to catalyze the oxidation reaction, and generate heat.
- B) Secondary Factors
  - a. Neutralization potential
  - b. Reaction with other minerals
- C) Tertiary Factors
  - a. Physical placement of the waste
  - b. Hydrological regime above and below the waste
  - c. Partial size
  - d. Permeability
  - e. Physical weathering characteristics

Based on close examination and results of tests conducted on Richardson Flat tailings there are several factors that will prevent the long-term acid generation from the tailings. These factors are as follows:

- A) Although sulfide minerals are present in the original ore body and the host rock, the major portion of the rock formation consists of carbonate-rich minerals as presented in Table 5-2. As can be seen from Table 5-2 sulfide minerals are present as a low percentage of total minerals in the tailings.
- B) Initially; the tailings were deposited in a slurry form. Therefore at the time of placement the tailings were saturated, much of this water was likely evaporated. Overtime free draining water has percolated from the tailings and achieved an equilibrium moisture condition at or close to the tailings field capacity. A seven inch to 10 feet soil cover consisting of low permeability clay was placed over the tailings impoundment. This clay cover system effectively sheds a major portion of the precipitation as surface run-off. Only at limited areas over the tailings impoundment where surface ponding is occurring will a small fraction of precipitation percolate into tailings.
- C) Oxygen penetration is very limited due to the presence of a clay cap and limited rate of surface water percolation. High moisture content and fine tailing particle size further minimizes the rate of oxygen penetration into the tailings.
- D) Ferric iron is present at very low levels indicating that the acid generation potential is low. During the production of tailings the ore is subjected to milling, chemical processes and wet depositional placement. These conditions will result in rapid oxidization and transformation of ferrous and ferric ions into ferric iron precipitation as iron hydroxide  $[(Fe(OH)_3)]$  manifested by yellow, orange or red deposits (referred to as yellowboy). There are no yellowboy deposits on the Site.
- E) Sulfide oxidizing bacteria are present at much lower numeration in tailings as compared to waste rock piles due to limited oxygen penetration, high moisture content, and low permeability.

Based on the factors discussed above and past experience with similar tailings impoundments in a similar environment, the potential for acid generation is very low and limited to the shallow (0 to 5 feet) depth tailings subjected to limited oxygen penetration. As previously stated the acid-base potential is positive in that there is net base potential in the tailings; should any acids become generated they will be immediately neutralized by the base compounds present in the tailings. However, because zinc can be



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soluble even under neutral pH conditions, zinc can still be in solution where water is in contact with tailings.

Assuming the primary factors are present in order to further evaluate the potential for acid production with in the tailings one can evaluate the secondary factors.

### **5.5.3 Neutralization Potential**

Static tests were conducted on representative samples of tailings to predict drainage quality by comparing the sample's maximum acid production potential (AP) with its maximum neutralization potential (NP). The results of static tests for the tailings are presented in Table 5-4.

The Net Neutralization Potential (NNP) is the difference between the NP and AP. If the NNP is positive this is an indication that the acid production is low risk and the neutralization capacity of tailings can overcome the acid potential. As it can be seen from Table 5-4 the surplus neutralization capacity for tailings is very high in excess of 50 tons of  $\text{CaCO}_3$  per ton of tailings. The NP/AP ratio is also an indicator of potential acid production generation. At this site NP/AP ratios are generally 1.5 and above indicating low potential for acid generation.

In order to calculate the time required to fully overcome surplus neutralization capacity is very difficult if not impossible. The main controlling factor will be the availability of oxygen to allow for continuous oxidization of tailings. Based on our past experience with various tailings (ESE 1995) the depth of oxygen penetration into tailings is limited to upper the 3 to 4 feet. This condition can further be verified with examination of the pH profile of tailings as function of depth. Table 4-11 presents the pH value of tailings vs. depth. As it can be seen from this table the tailings pH vary from 7.3 to 7.7 at two to six feet below the ground surface. Therefore, the pH data do not indicate that the tailings are generating acid in the oxidized zone of the tailings vertical profile.

### **5.5.4 Chemical Stability of Sediments in South Diversion Ditch and Wetlands**

The chemical environment operating in the South Diversion Ditch is dynamic, allowing for elevated dissolved zinc concentrations in the central reach but then transferring zinc to the solid phase in the lower reach. Metals removal likely occurs by some combination of the following processes:

- Biologically mediated precipitation as sulfide minerals
- adsorption on solid mineral phases or decaying organic matter

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- coprecipitation with other metals such as manganese
- and to a lesser degree uptake by wetland plants

Although adsorption processes may have a limit, bio-attenuation mechanisms and coprecipitation processes are essentially unlimited as long as the present ecology in the ditch is maintained. Although not initially requested, acid-base potential tests were also run on six (6) sediment samples plus one duplicate. The acid-base potential data (Table 5-4) for the six sediment samples and one duplicate indicate that the neutralization potential is between 62 and 106 tons  $\text{CaCO}_3$ /1000 tons tailings (8.2 to 20.3 percent lime) indicating that there is a large excess base potential between 52 and 90 tons  $\text{CaCO}_3$ /1000 tons of tailings. The fraction of hot water extractable sulfur is between 0.04 and 0.53 percent compared to an acid extractable fraction of between 0.55 and 2.89 percent. Because the sediments have a lower fraction of extractable sulfur with a similar buffering capacity as the tailings, it would be very difficult to use up the neutralization potential and increase the leaching of sulfide minerals above present levels. The pH of water in the diversion ditch during this study has been between about 6.7 and 8.5. Therefore, very little, if any, of the neutralization capacity is consumed and the sediments should be stable as long as the current ditch operations are maintained.

## **6.0 BASELINE RISK ASSESSMENT**

A baseline human health risk assessment (BHHRA) for recreational visitors to the Site was conducted by the EPA and a draft version was released in May 2002. EPA will provide an ecological risk assessment when United Park completes the ecological site assessment in the spring of 2003. The Draft BHHRA and its conclusions are summarized below. Appendix 6 contains the Draft Baseline Human Health Risk Assessment.

Under the BHHRA, arsenic and lead were identified as chemicals of potential concern (COPCs) for the site through a four-step screening process. Two separate recreational use scenarios were evaluated: low intensity users such as picnickers, hikers, and bikers (young child to adult) and high intensity users such as horseback riders, ATV users, dirt-bikers, soccer and baseball players (teenage to adult). Calculations were conducted using both central tendency exposure (CTE) and reasonable maximum exposure (RME) values for each scenario.

Several exposure pathways were determined to be potentially significant and were evaluated quantitatively for each of the two recreational use scenarios. For the low intensity user, five pathways

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were evaluated quantitatively: ingestion of soil/tailings, ingestion of surface water, dermal exposure to surface water, ingestion of sediment, and inhalation of particulates in air. For the high intensity user, two pathways were evaluated quantitatively: ingestion of soil/tailings, and inhalation of particulates in air. For arsenic, risk calculations for all scenarios using both CTE and RME values showed that all noncancer hazard indices were less than one, indicating that no appreciable noncancer health effects are expected to occur. All calculated cancer risks were below  $1 \times 10^{-4}$ .

Lead was evaluated using the Integrated Exposure, Uptake and Biokinetic (IEUBK) model for children, and the Bower's model for adult receptors. Both models predicted blood lead levels below the EPA's health-based goal of a 5% probability of exceeding a blood lead level of  $10 \mu\text{g/dL}$  for all recreational use scenarios.

Thus, the results of the BHHRA indicate that the concentrations of lead and arsenic at the site are not expected to pose a risk to recreational users of the Site above a level of regulatory concern.

## **7.0 SUMMARY AND CONCLUSIONS**

The objective of the focused RI at Site is to assess the nature and extent of contamination and the potential risks to the environment and human health associated with historical operations at the Site. The purpose of this report is to document results of this remedial investigation and incorporate findings from previous site investigations conducted by others at the Site. Following EPA and UDERR concurrence on the RI report, UNITED PARK will prepare a Feasibility Study analyzing alternatives to address potential excess risks, if any. Presented in this section are conclusions regarding the nature and extent of contamination and fate and transport of site contaminants. After EPA has completed the ecological risk assessment this section of the report may be modified.

### **7.1 Summary of Nature and Extent of Contamination**

#### **Surface Water**

- The data presented in Sections 4.1.1 through 4.1.3 indicate that metals concentrations are substantially lower in water discharged from the South Diversion Ditch (RF6-2) than in Silver Creek itself (RF7-2 and RF8). In fact, zinc concentrations are two orders of magnitude lower at RF6-2 than in Silver Creek. Zinc concentrations at RF6-2 are only slightly greater than background concentrations measured at RF-1 and RF-2 in the ephemeral drainage upstream from the tailings impoundment.

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- Surface waters in both upstream and downstream locations in Silver Creek contain zinc concentrations that exceed the chronic and acute aquatic wildlife standard for zinc. This is in contrast to the metals concentrations measured in the downstream end of the diversion ditch (RF6-2) which are below both the chronic and acute aquatic wildlife standard for zinc.
- Zinc concentrations exceed water quality criteria in the upper section of the diversion ditch (roughly from RF-4 to RF-11).
- Water discharging from the diversion ditch and entering the wetlands meets all applicable water quality criteria, whereas water from Silver Creek entering the wetlands and converging with the diversion ditch water does not meet applicable water quality criteria for zinc.

### **Groundwater**

- Groundwater sampling results indicate that although some seasonally elevated zinc concentrations are observed, in general the groundwater contained within the tailings south of the diversion ditch has much lower concentrations of metals than the groundwater in the Silver Creek alluvial aquifer. Much of the groundwater south of the diversion ditch is captured by the ditch. Average dissolved zinc concentrations in groundwater associated with the tailings are generally about 500 times lower than concentrations measured in the upgradient Silver Creek alluvial aquifer. Based on these data, it does not appear that the Richardson Flat tailings are contributing zinc or other metals to the Silver Creek alluvial aquifer.
- Beyond seepage across the tailings embankment, there is no hydraulic connection between the groundwater stored in the tailings and underlying and adjacent to shallow alluvial aquifers (*See*, MWH Americas report Appendix 5).
- There is no apparent hydraulic connection between groundwater stored in the tailings and the underlying aquifer(s) within the Keetley Volcanic rocks developed as a groundwater supply by downstream Public Water Systems (*See*, MWH Americas report Appendix 5).
- First-order approximations of seepage rates through the tailings embankment range from approximately 0.6 to 63 gallons per day (*See*, MWH Americas report Appendix 5). This volume of water is insufficient to adversely impact the wetlands area.
- Pumping wells serving Public Water Systems along Silver Creek do not capture groundwater stored in Keetley Volcanic rocks underlying Richardson Flat (*See*, MWH Americas report Appendix 5).
- Groundwater quality at piezometer RT-7 indicates groundwater within the wetland area between the main embankment and Silver Creek is not impacted by mine wastes.

### **Soils**

- On-site soils data indicate that the tailings cover is greater than 1.0 feet deep on the southern half of the impoundment and more than six inches deep on the northern half. Average surface soil concentrations for lead are less than 400 ppm. There are a few localized areas of the cover where surface lead concentrations exceed 400 ppm.

## **DRAFT**

- Off-site soils data indicate that the extent of wind blown tailings is generally limited to areas immediately adjacent to the impoundment. Samples collected north of State Highway 248 indicate that the average lead concentration for this transect is 128 ppm. Transect 2 located immediately south of the tailings impoundment reveals that there are areas of exposed tailings along this transect. Transect 3 average lead concentrations are 142 ppm which are elevated above background however, the results of risk assessment indicates that these levels do not pose a risk to human health or the environment.
- Sample data show that the diversion ditch sediments contain metals at all locations sampled. XRD data indicate that there are sulfide minerals present in the sediments indicating that biogeochemical processes are occurring in the ditch sediments. The sulfide minerals are likely less bioavailable than other mineral phases.
- Tailings data indicate that there is net base potential in the tailings meaning that there are more alkaline or basic compounds in the tailings than acid generating compounds. Under current operating conditions it is unlikely that the tailings will become acidic. The average tailings pH is 7.5 Su. SPLP data from unsaturated tailings indicate that metals such as lead and zinc will leach, however, Site groundwater data from wells RT-13, RT-14, and RT-15 (completed in tailings) suggest that metals leached from tailings are re-saturated after being above the water table for an extended period of time.
- The Draft Human Health Risk Assessment for Recreational Visitors, conducted by EPA, has determined that there are no unacceptable risks to the targeted population at this site.

## **DRAFT**

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## **List of Tables**

- 1-1 Richardson Flat Historical Groundwater Analytical Results
- 1-2 Comparison of 1985, 1992 and 1998 Groundwater Data
- 1-3 Historical Surface Water Analytical Results
- 1-4 1999 Surface Water Data
  
- 2-1 Surface and Groundwater Sampling Frequency
  
- 3-1 Surface and Groundwater Field Data
- 3-2 Onsite Soil Cover Thickness
  
- 4-1 Surface Water Analytical Results
- 4-2 Low Detection Limits Hg Water Analytical Results
- 4-3 Screening of Dissolved Metal Concentrations in Surface Water
- 4-4 Background Surface Water Data
- 4-5 Floodplain Tailings Surface and Groundwater Analytical Results
- 4-6 Screening of Floodplain Tailings Area Metal Concentrations
- 4-7 Groundwater Analytical Results
- 4-8 Screening of Total Metals Concentrations in Groundwater
- 4-9 Onsite Soil Cover Analytical Results
- 4-10 Offsite Soil Cover Analytical Results
- 4-11 Sediment Analytical Results
- 4-12 Tailings Analytical Results
- 4-13 Soil pH Analytical Results
- 4-14 Tailings South of the Diversion Ditch Analytical Results
- 4-15 Background Soil Analytical Results
- 4-16 Background Soil Data
- 4-17 Study Area Boundary Analytical Results
  
- 5-1 Summary of Chemistry Data for Tailings
- 5-2 Summary of Mineralogy Data for Tailings
- 5-3 Synthetic Precipitation Leaching Procedure (SPLP) Results
- 5-4 Acid – Base Potential Results
- 5-5 Cation Exchange Capacity Results
- 5-6 Comparison of Mineralogy of Tailings and South Diversion Ditch Sediments



**TARGET SHEET**  
EPA REGION VIII  
**SUPERFUND DOCUMENT MANAGEMENT SYSTEM**

DOCUMENT NUMBER: 2008740

SITE NAME: RICHARDSON FLAT TAILINGS

DOCUMENT DATE: 12/17/2002

**DOCUMENT NOT SCANNED**

Due to one of the following reasons:

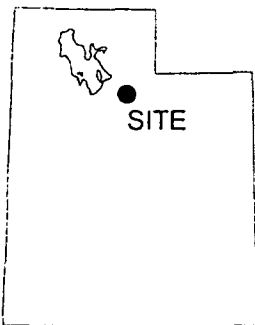
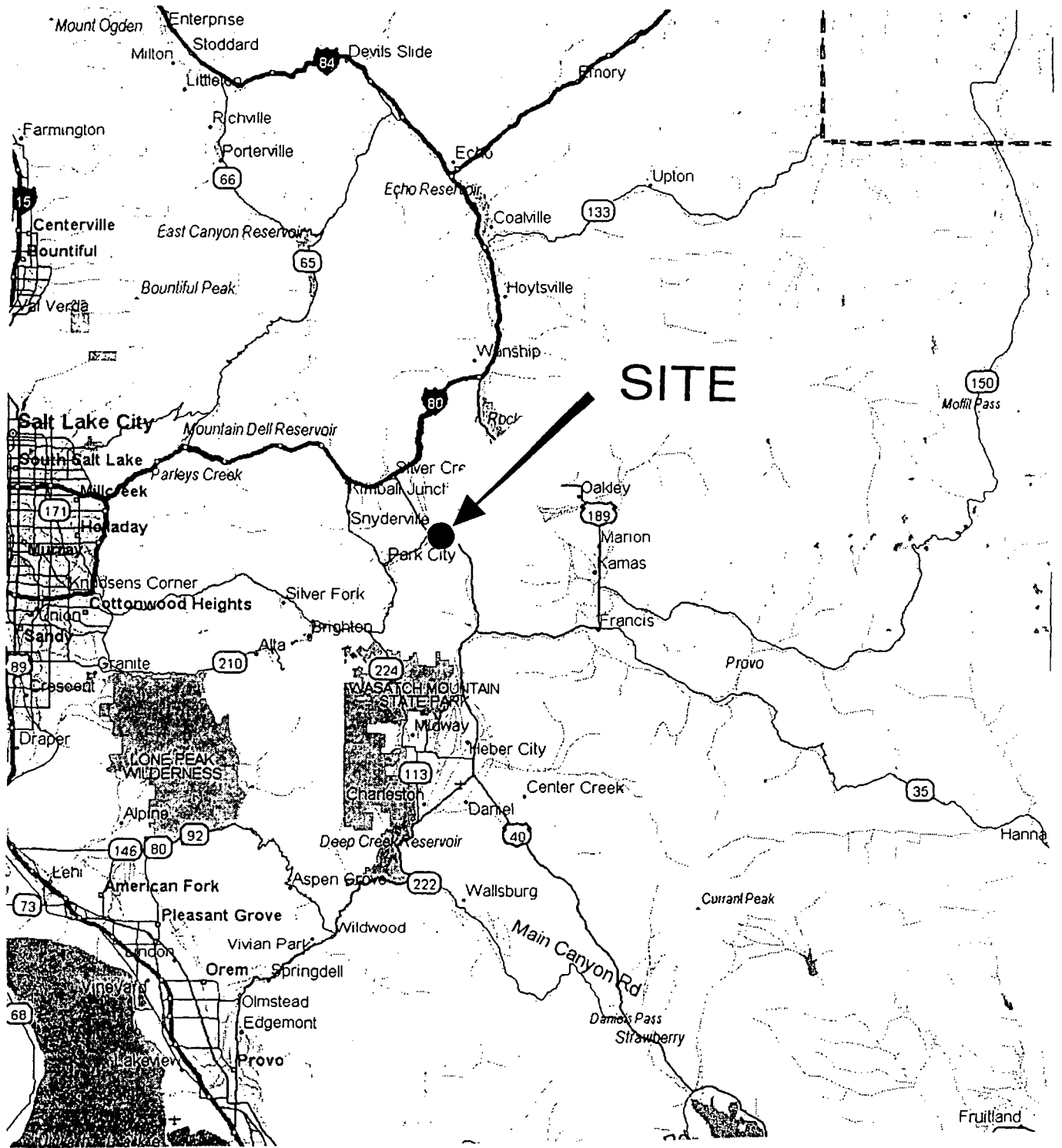
- ☐ PHOTOGRAPHS
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- ☐ AUDIO/VISUAL
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(Data Packages, Data Validation, Sampling Data, CBI, Chain of Custody)

**DOCUMENT DESCRIPTION:**

TABLES 1-1 thru 1-4, 2-1, 3-1, 3-2, 4-1 thru 4-17, & 5-1 thru 5-6 (See  
Table of Contents)  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

## List of Figures

- 1-1 Site Location Map
- 1-2 Site Vicinity Map
- 1-3 Site Features and Boundary Map
- 1-4 Historical Surface and Groundwater Sample Location Map
  
- 2-1 Surface and Groundwater Sample Location Map
- 2-2 Floodplain Area Sample Location Map
- 2-3 Soil Boring Location Map
- 2-4 Onsite Soil Cover Sample Location Map
- 2-5 Site Wind Rose
- 2-6 Offsite Soil Cover Sample Location Map
- 2-7 Sediment Sample and Tailings Test Pits Location Map
- 2-8 Tailings South of the Diversion Ditch Sample Location Map
- 2-9 Background Soil Sample Location Map
- 2-10 Study Area Boundary Sample Location Map
  
- 3-1 Tailings South of Diversion Ditch Cover Map
  
- 4-1 Dissolved Zinc Time Series, Surface Water
- 4-2 Total Lead and Zinc Time Series, Groundwater
- 4-3 Floodplain Tailings Area Potentiometric Surface Map
- 4-4 Silver Creek Area Hydrogeologic Cross Sections
- 4-5 Onsite Soils Cover Analytical Results
  
- 5-1 Schematic Model of Contaminant Transport Pathways
- 5-2 pH/Eh Plot
- 5-3 Surface Complexation of Dissolved Metal Ions
- 5-4 Time Series Plot of Dissolved Zinc Concentrations in Upper Aquifer South of Tailings Impoundment
- 5-5 Dissolved Zinc Concentrations in South Diversion Ditch
- 5-6 Metals Concentrations in South Diversion Ditch Sediments
- 5-7 Comparison of Trace Metal Ratios in Tailings and Diversion Ditch Sediments
- 5-8 Zinc Concentrations in Sediment and Water Along South Diversion Ditch
- 5-9 Lead Concentrations in Sediment and Water Along South Diversion Ditch
- 5-10 Plots of Dissolved Zinc vs. Key Chemical Parameters
- 5-11 Temperature and pH in Water Along South Diversion Ditch
- 5-12 Cation Exchange Capacity vs. Metals Concentrations in South Diversion Ditch Sediments
- 5-13 Piper Plot
- 5-14 Time Series Plot of Dissolved Zinc Concentrations in Silver Creek Alluvium
- 5-15 Histogram of Dissolved Zinc Concentrations



UTAH



NOT TO SCALE

## RICHARDSON FLAT RI

FIGURE 1-1  
SITE LOCATION MAP

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8138 SOUTH STATE ST.  
SUITE 2A  
MIDVALE, UT 84047  
801-255-2626

APRIL 2002

ri-site-location-map-dwg

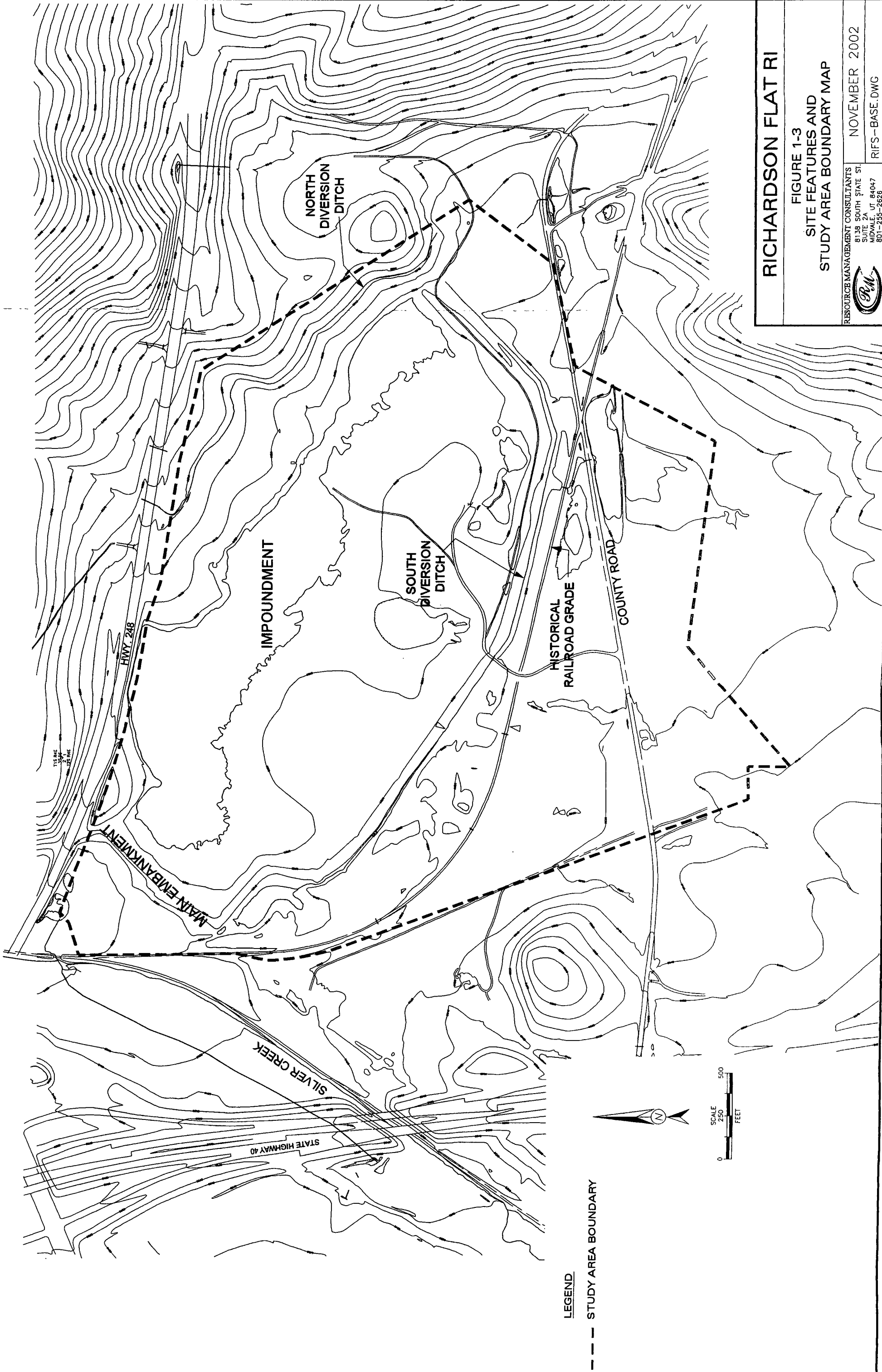


# RICHARDSON FLAT RI

FIGURE 1-2  
SITE VICINITY MAP

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8138 SOUTH STATE ST.  
SUITE 200  
MIDVALE, UT 84047  
801-255-2626  
parkcity-quads-rifs.dwg

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FEET



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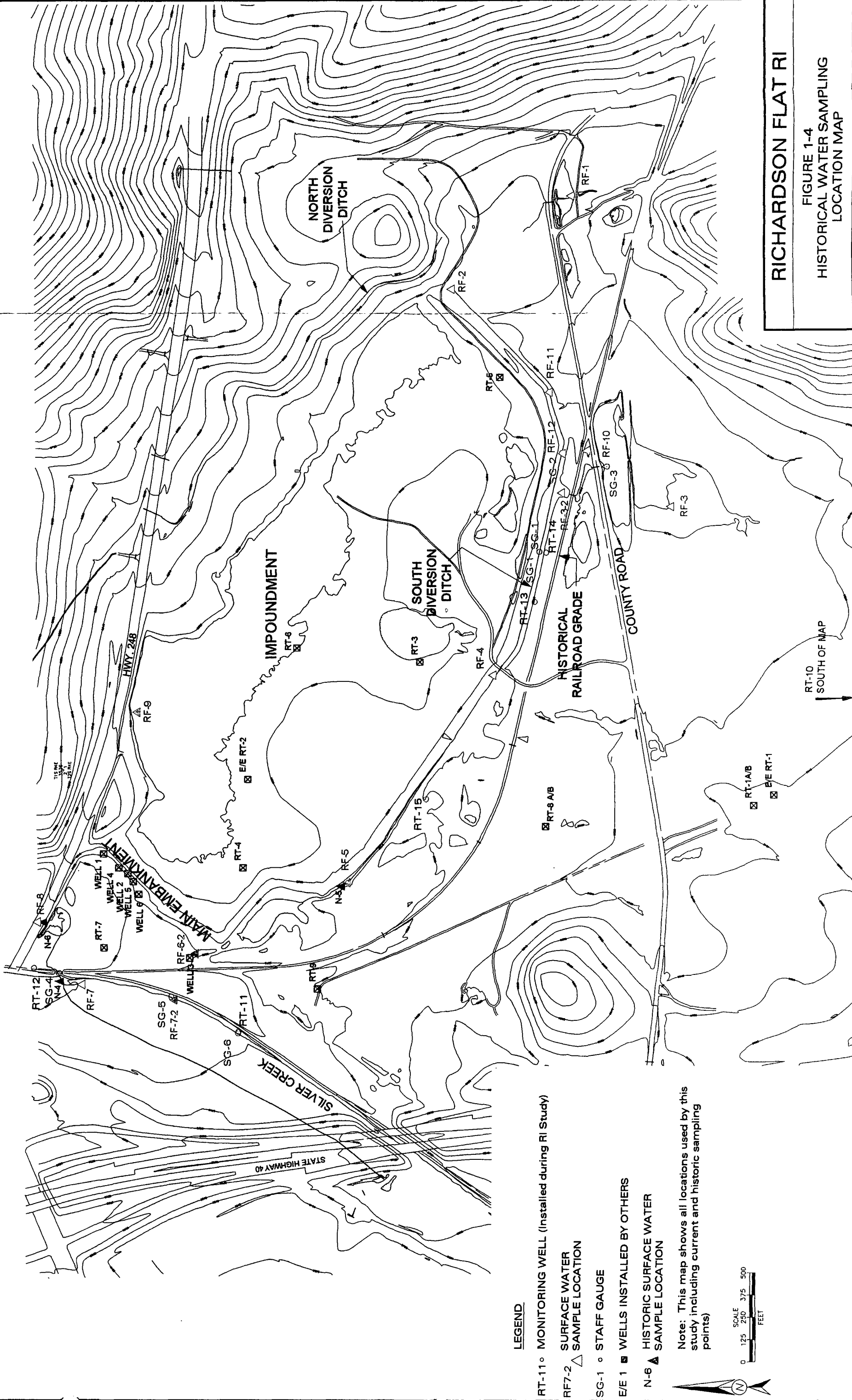
# RICHARDSON FLAT RI

FIGURE 1-3  
SITE FEATURES AND  
STUDY AREA BOUNDARY MAP

RESOURCE MANAGEMENT CONSULTANTS  
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SUITE 2A  
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**LEGEND**

RT-11 ○ MONITORING WELL (Installed during RI Study)

RF7-2 △ SURFACE WATER

SG-1 □ SAMPLE LOCATION

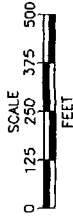
E/E 1 ○ STAFF GAUGE

N-6 △ WELLS INSTALLED BY OTHERS

N-6 △ HISTORIC SURFACE WATER

N-6 △ SAMPLE LOCATION

Note: This map shows all locations used by this study including current and historic sampling points)



**RICHARDSON FLAT RI**

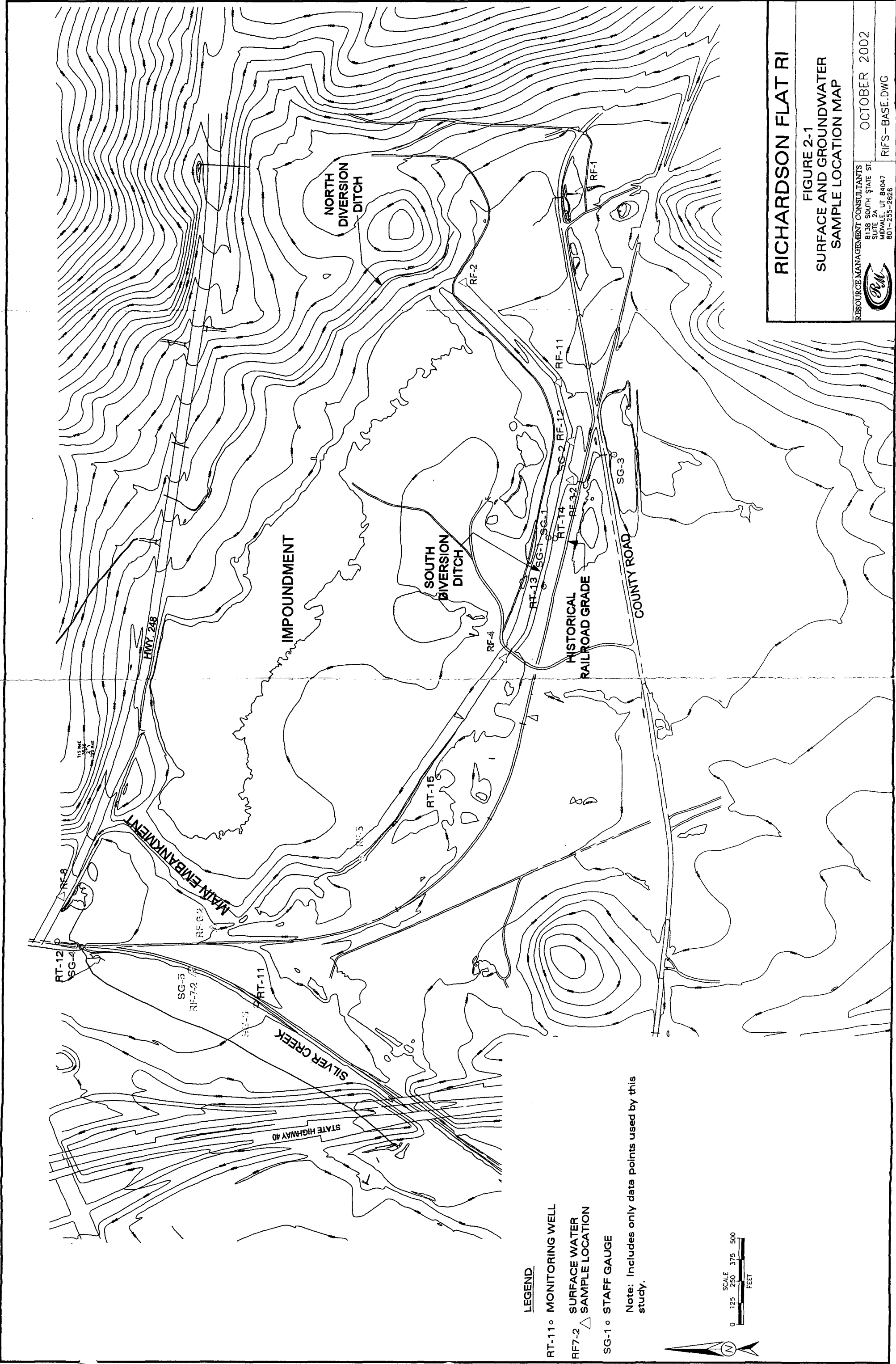
**FIGURE 1-4  
HISTORICAL WATER SAMPLING  
LOCATION MAP**

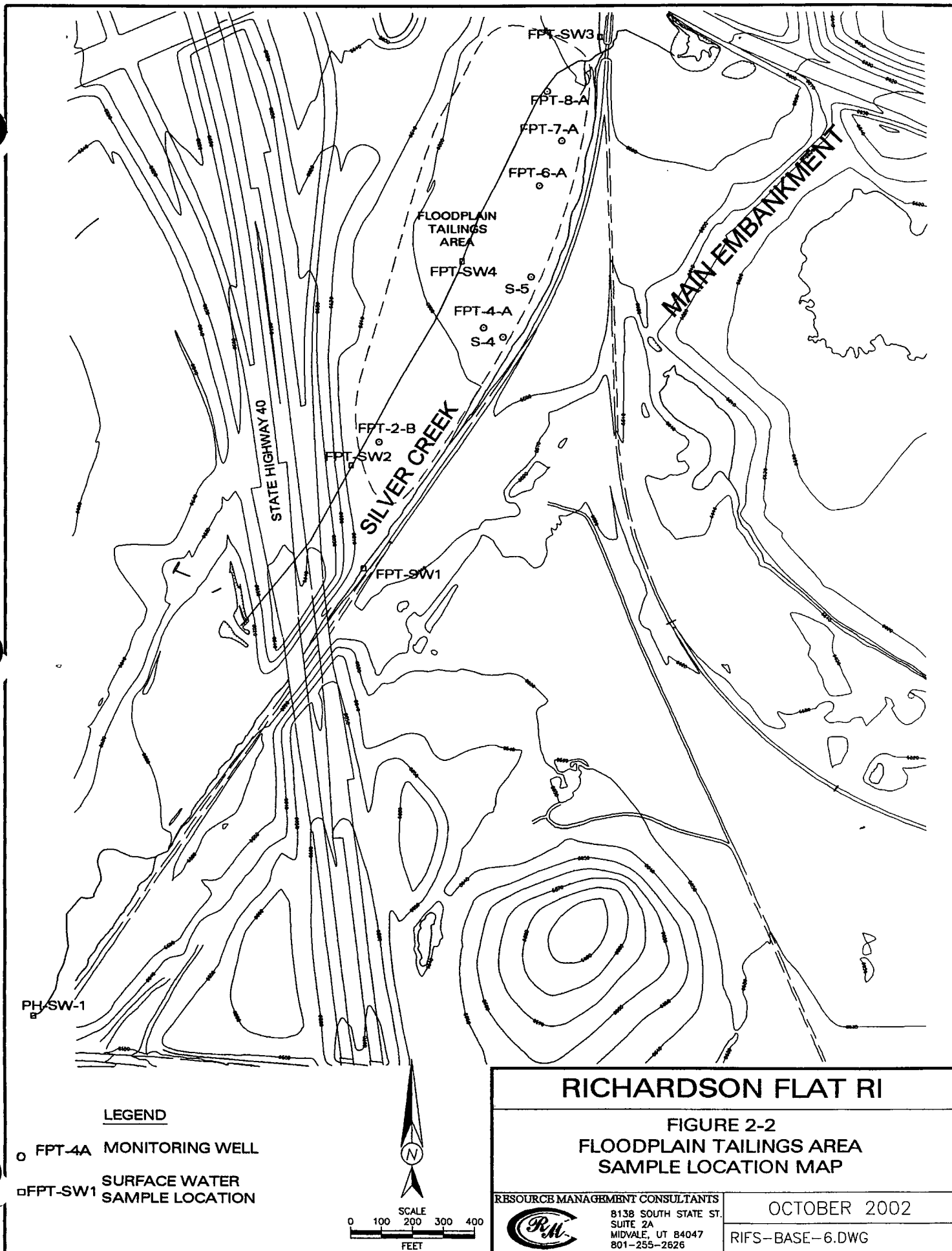
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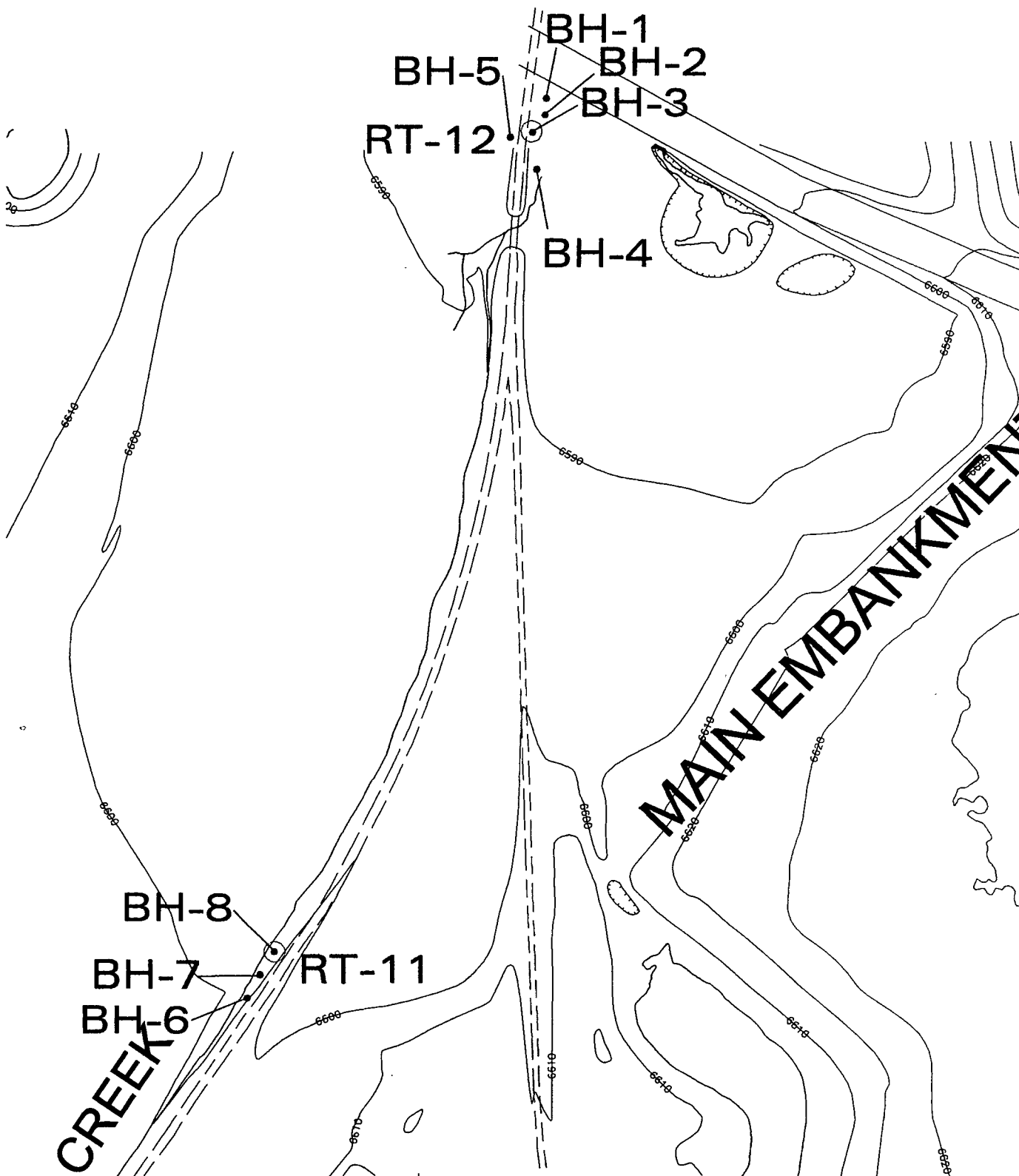
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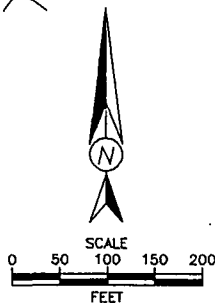






**LEGEND**

- MONITORING WELL
- SOIL BORING



**RICHARDSON FLAT RI**

**FIGURE 2-3  
SOIL BORING LOCATION MAP**

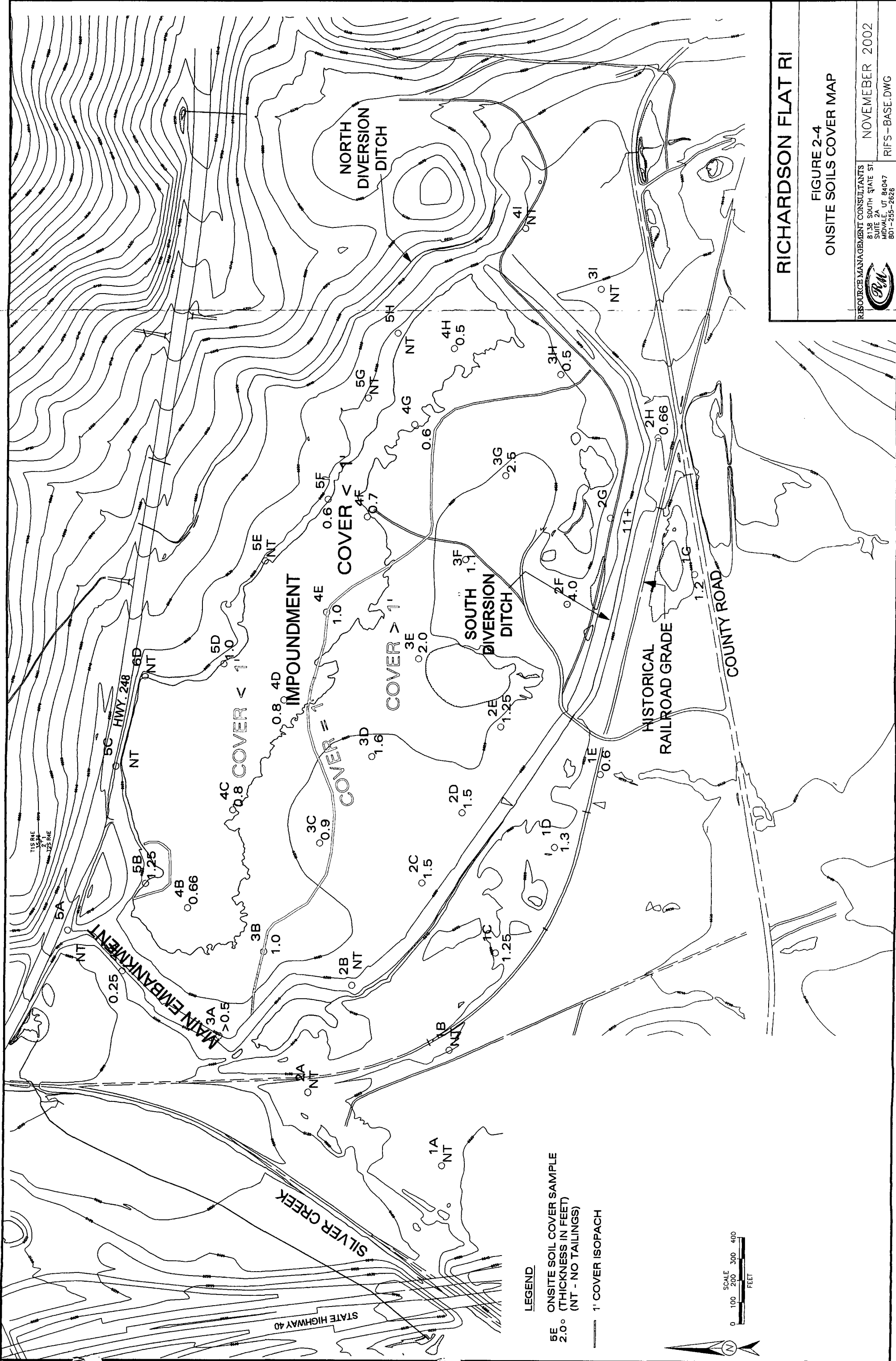
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SUITE 2A  
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**RICHARDSON FLAT RI**

FIGURE 2-4

ONSITE SOILS COVER MAP

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SUITE 2A MIDVALE, UT 84047

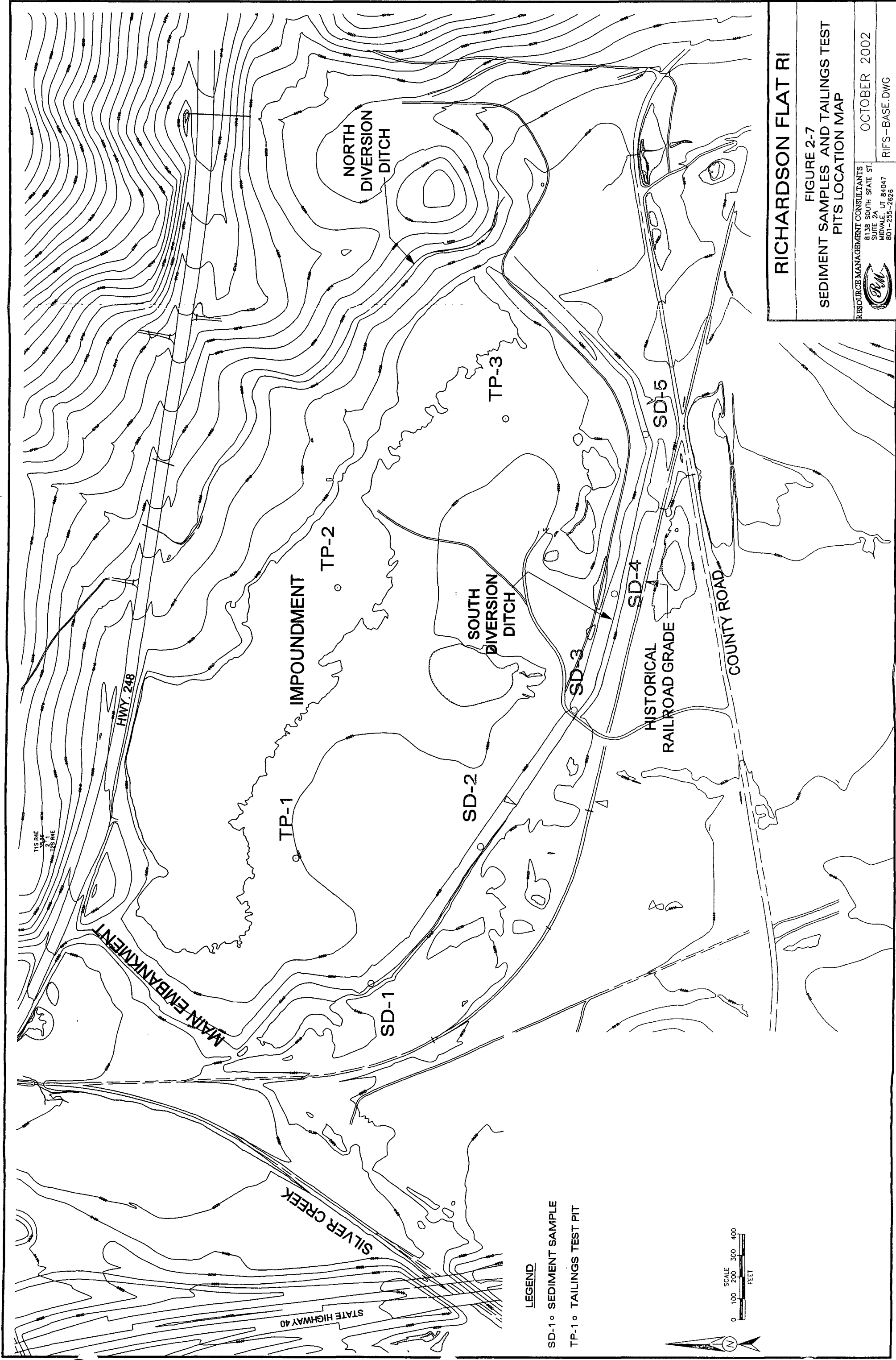
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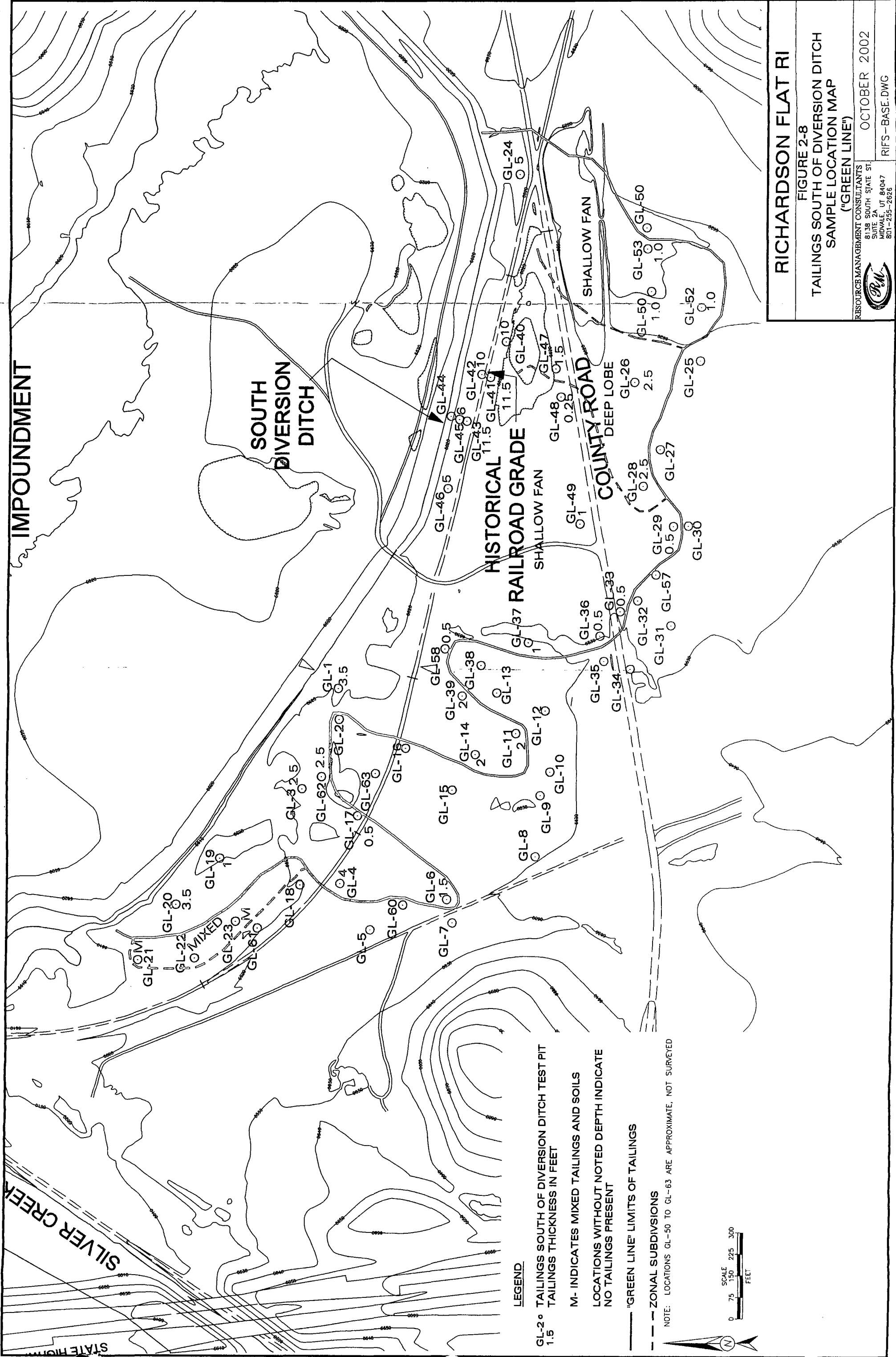
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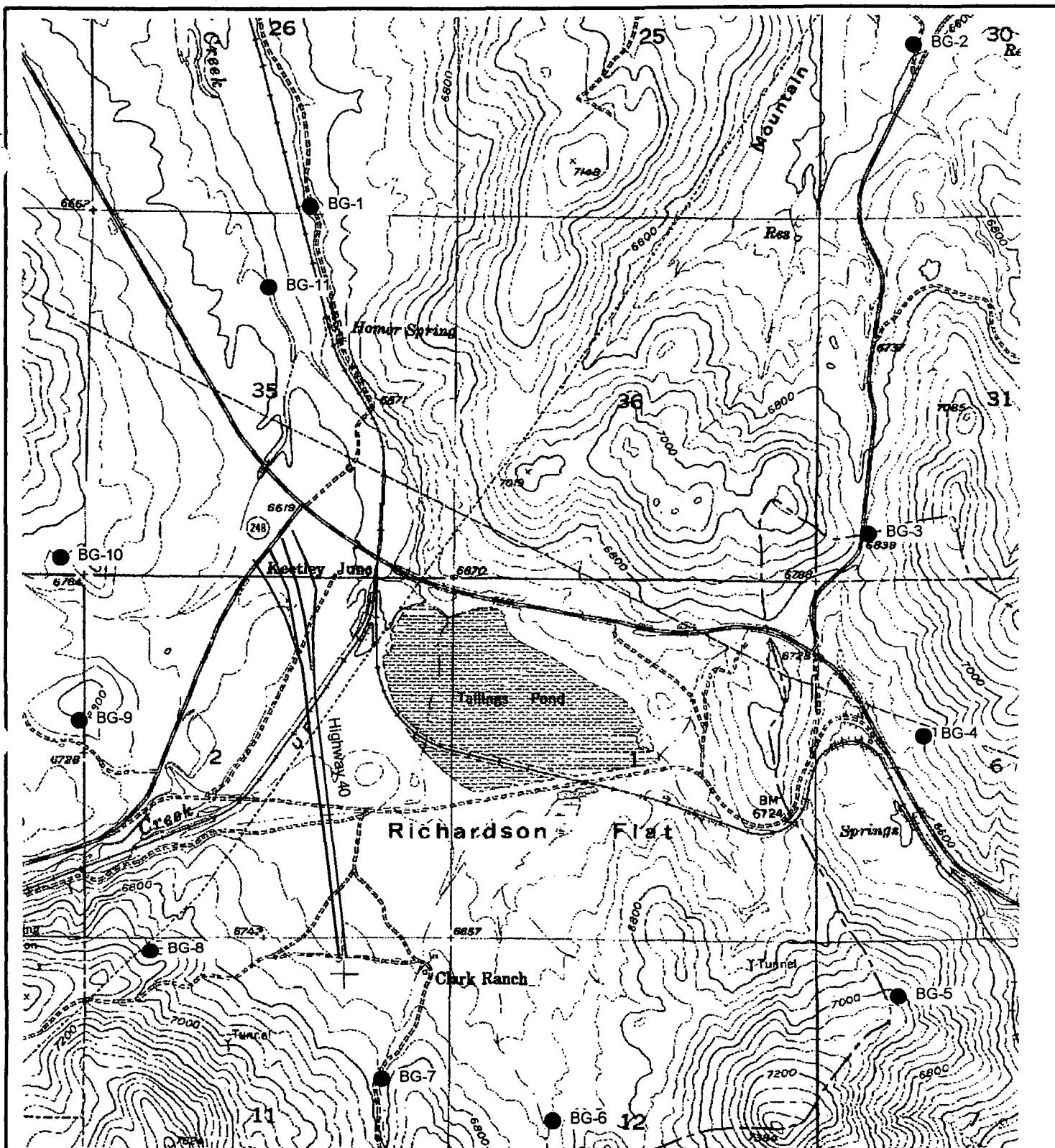
**RICHARDSON FLAT RI**

FIGURE 2-8  
TAILINGS SOUTH OF DIVERSION DITCH  
SAMPLE LOCATION MAP  
("GREEN LINE")

RESOURCE MANAGEMENT CONSULTANTS  
813B SOUTH STATE ST.  
SUITE 2A  
BOWDOEN, UT 84047  
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# LEGEND

- BACKGROUND SOIL SAMPLE LOCATION



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## RICHARDSON FLAT RI

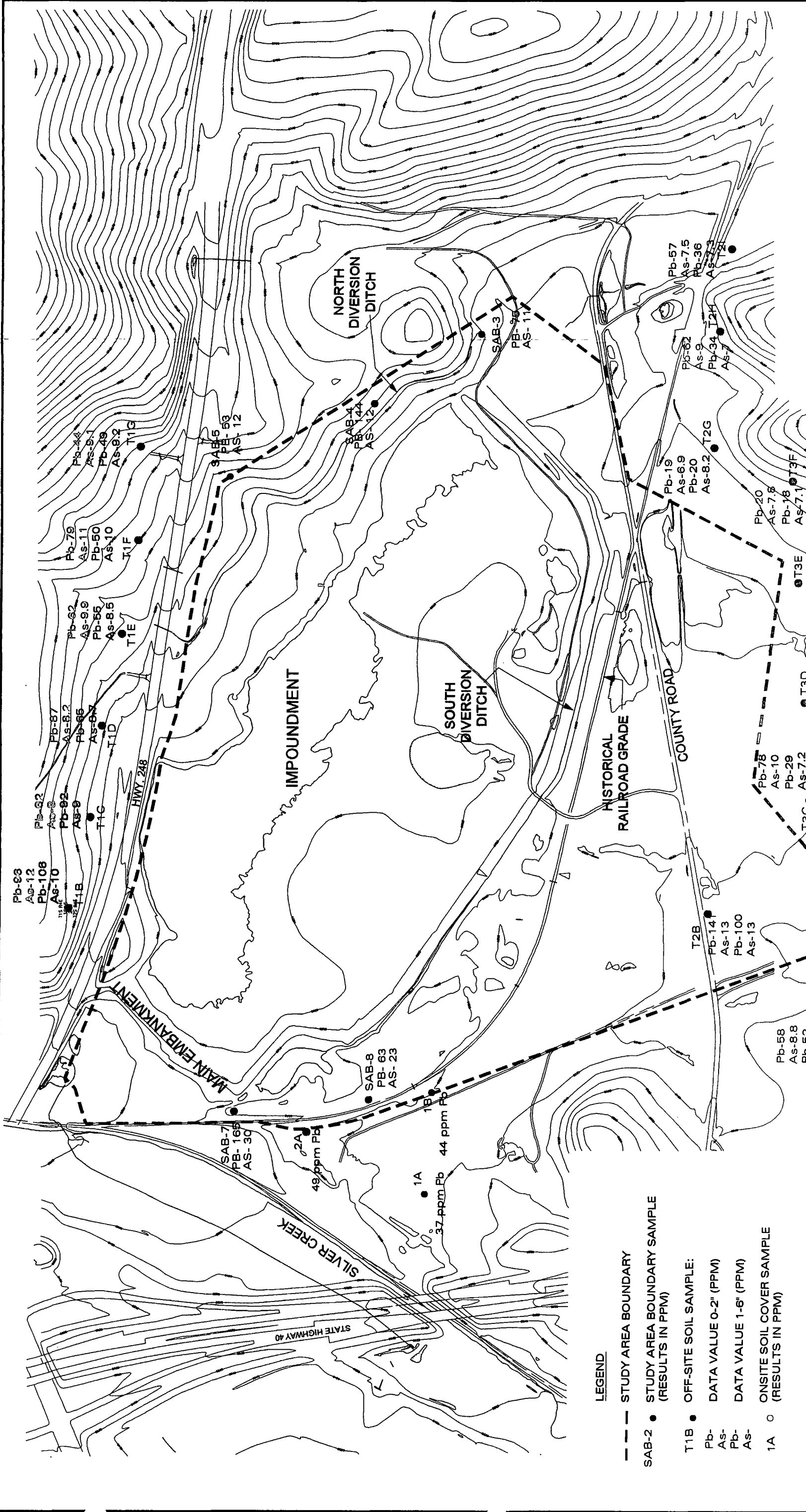
### FIGURE 2-9 BACKGROUND SAMPLE LOCATION MAP

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- LEGEND**
- STUDY AREA BOUNDARY
  - SAB-2 • STUDY AREA BOUNDARY SAMPLE (RESULTS IN PPM)
  - T1B • OFF-SITE SOIL SAMPLE:
    - Pb- DATA VALUE 0-2" (PPM)
    - As- DATA VALUE 1-6" (PPM)
    - Pb- DATA VALUE 1-6" (PPM)
    - As- DATA VALUE 1-6" (PPM)
  - 1A ○ ONSITE SOIL COVER SAMPLE (RESULTS IN PPM)

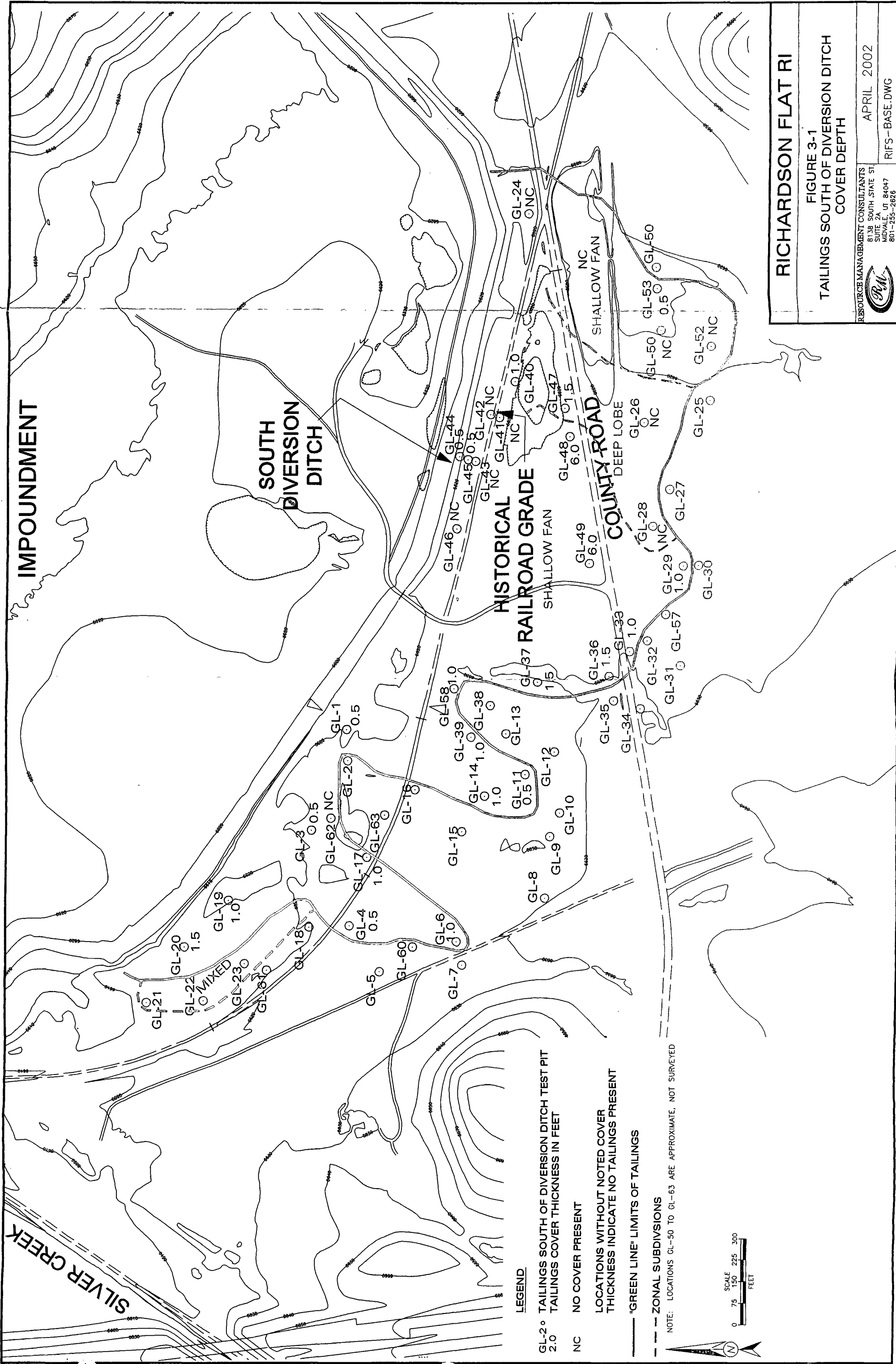
**UNITED PARK CITY MINES**

**FIGURE 2-10**  
**STUDY AREA BOUNDARY SAMPLES**

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8138 SOUTH STATE ST.  
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**RICHARDSON FLAT RI**

**FIGURE 3-1**  
**TAILINGS SOUTH OF DIVERSION DITCH**  
**COVER DEPTH**

**Figure 4-1**  
**Dissolved Zinc Time Series, Surface Water**

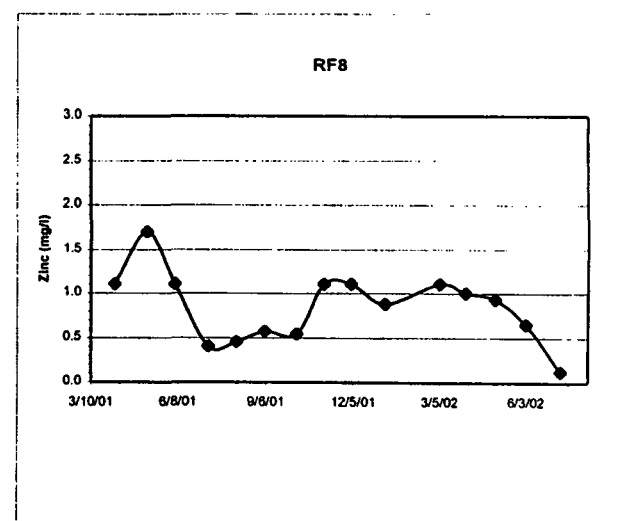
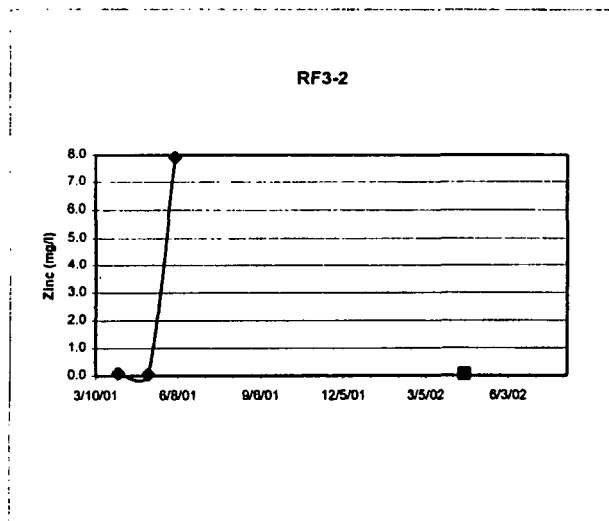
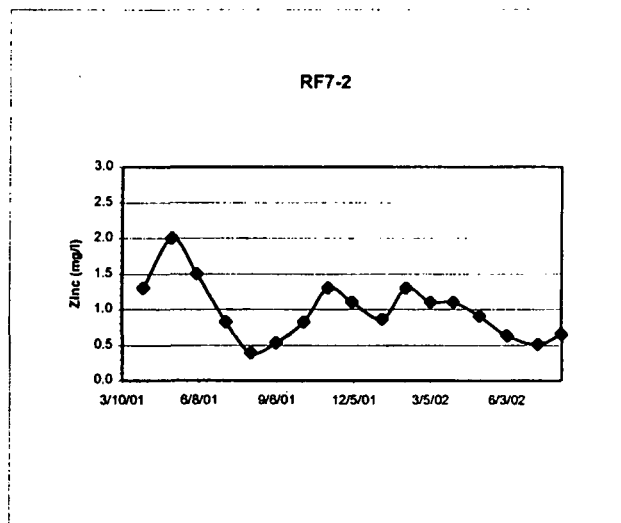
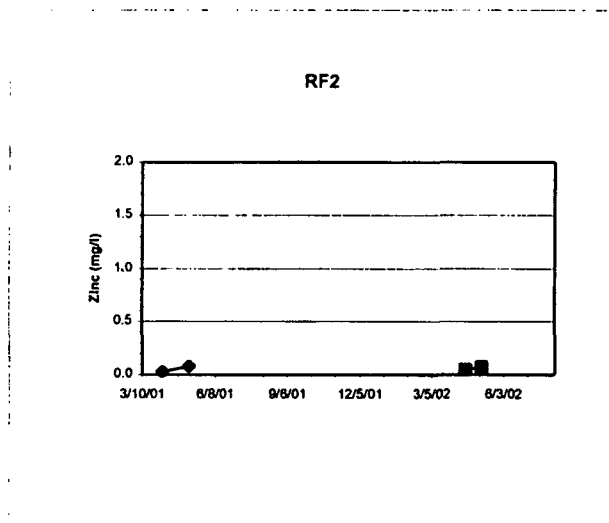
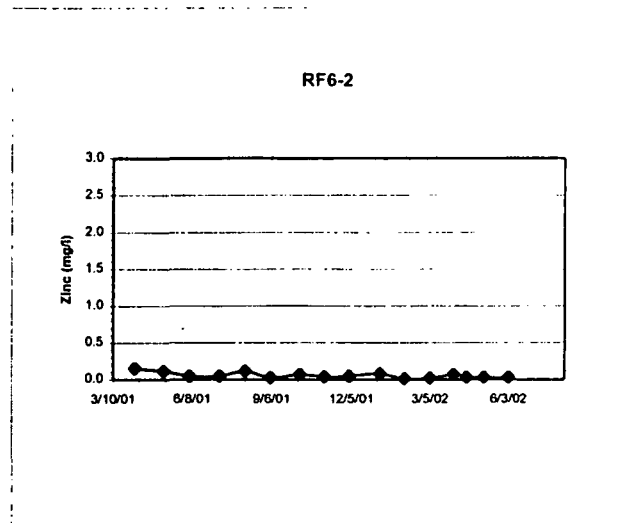
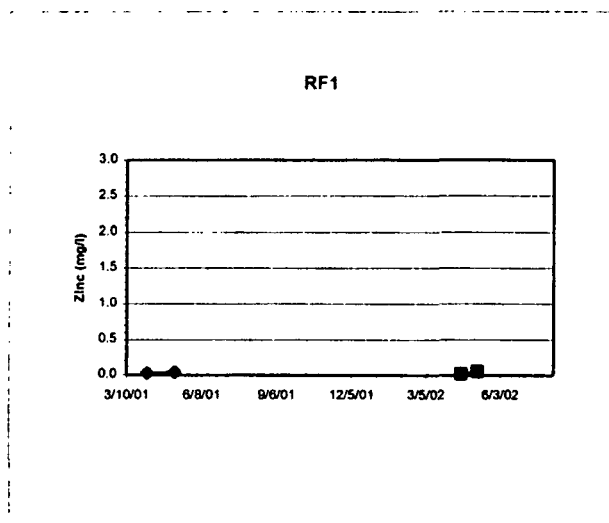
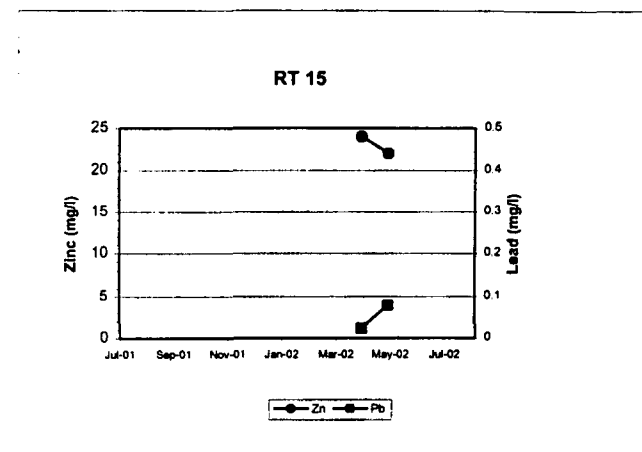
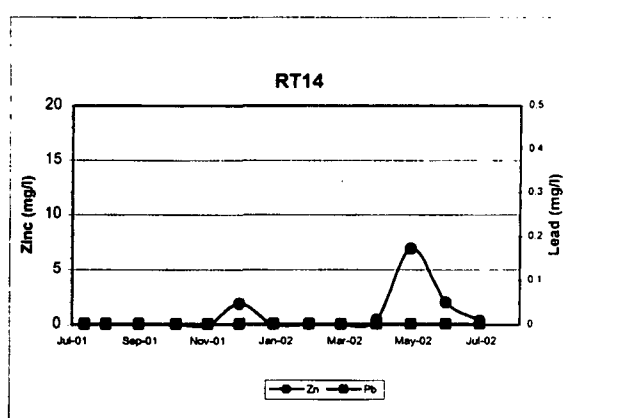
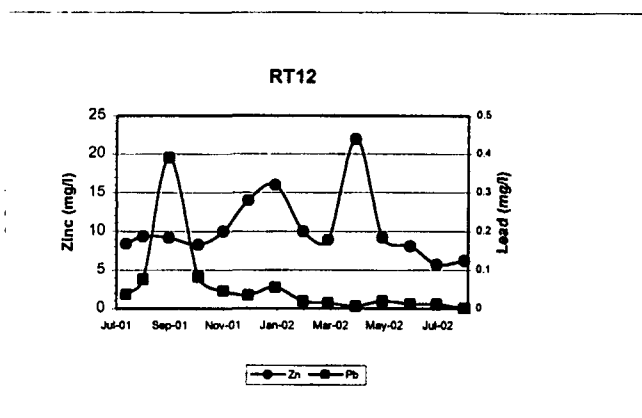
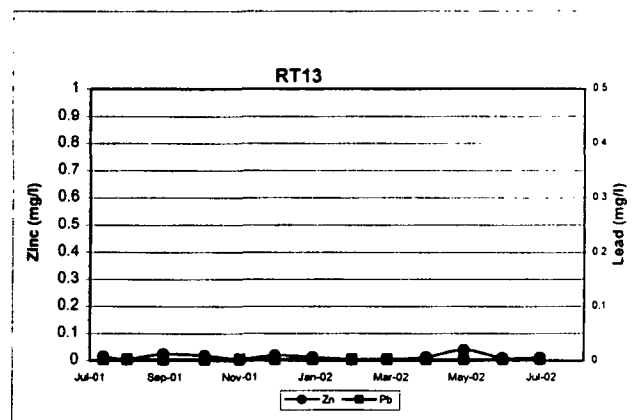
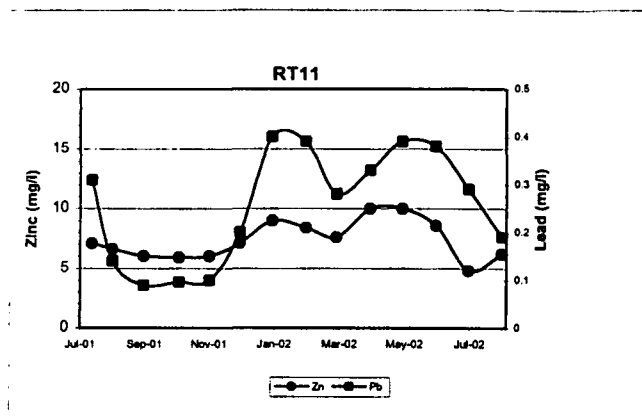
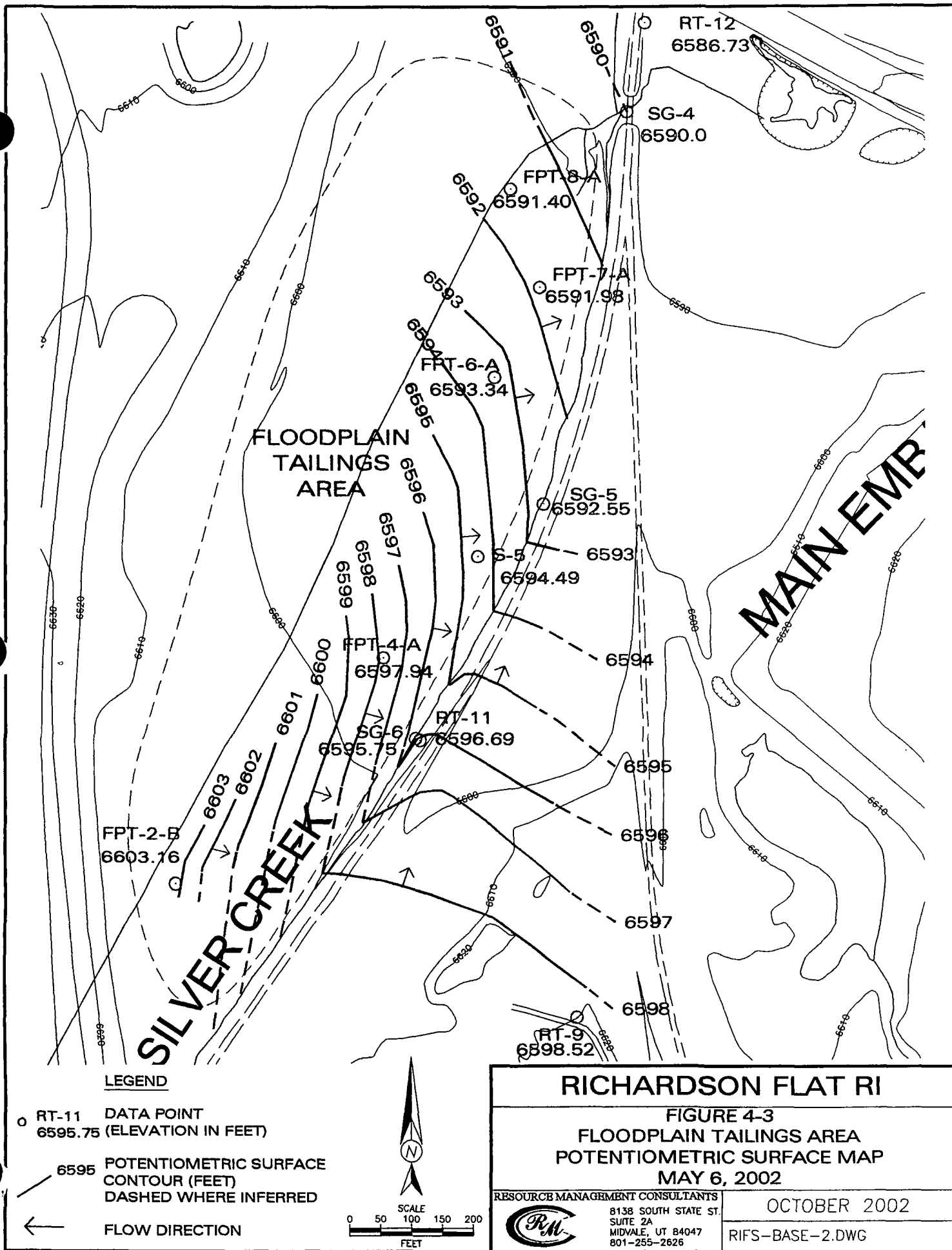
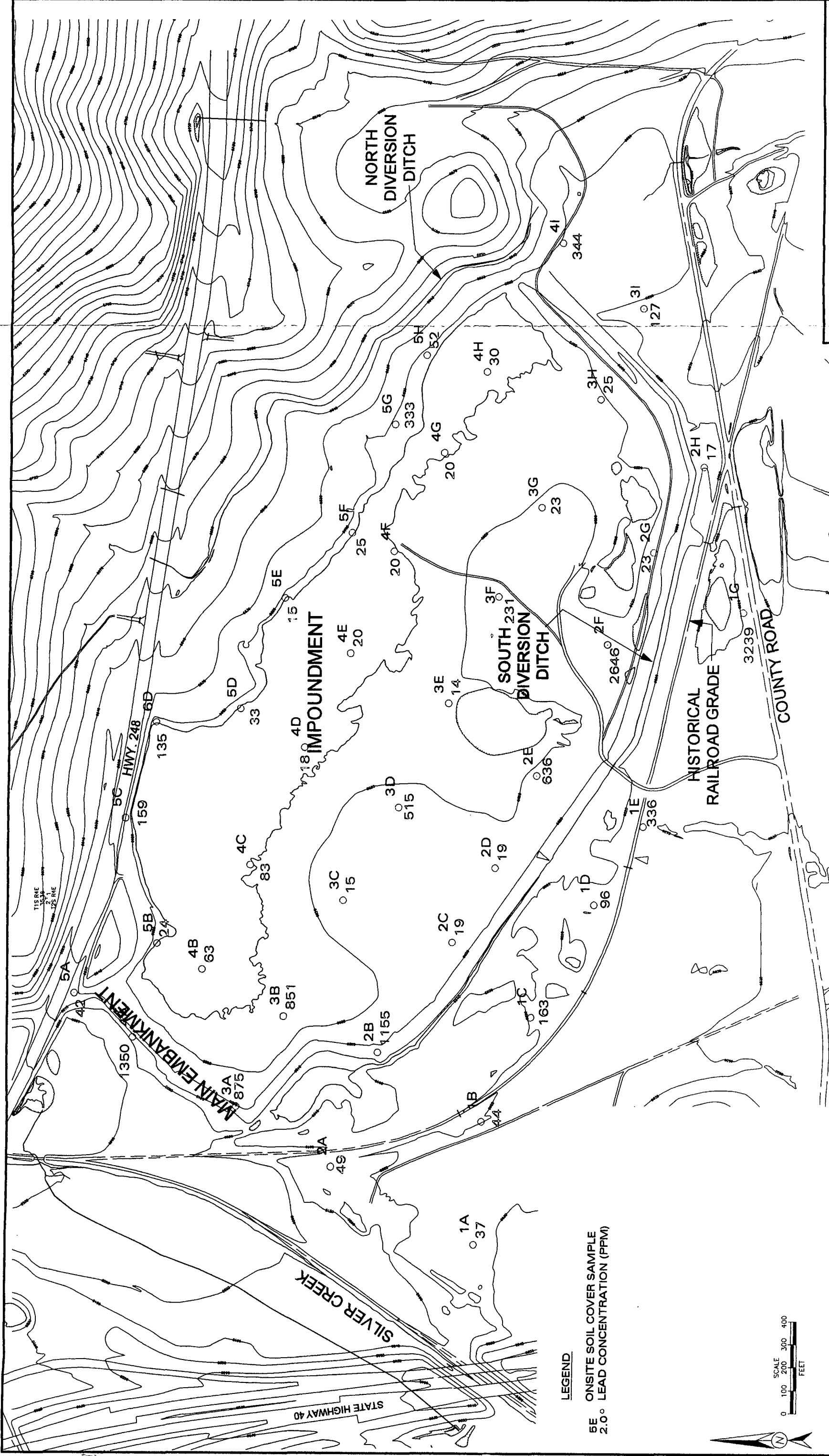


Figure 4-2  
Total Zinc and Lead Time Series, Groundwater









**LEGEND**  
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 2.0° LEAD CONCENTRATION (PPM)




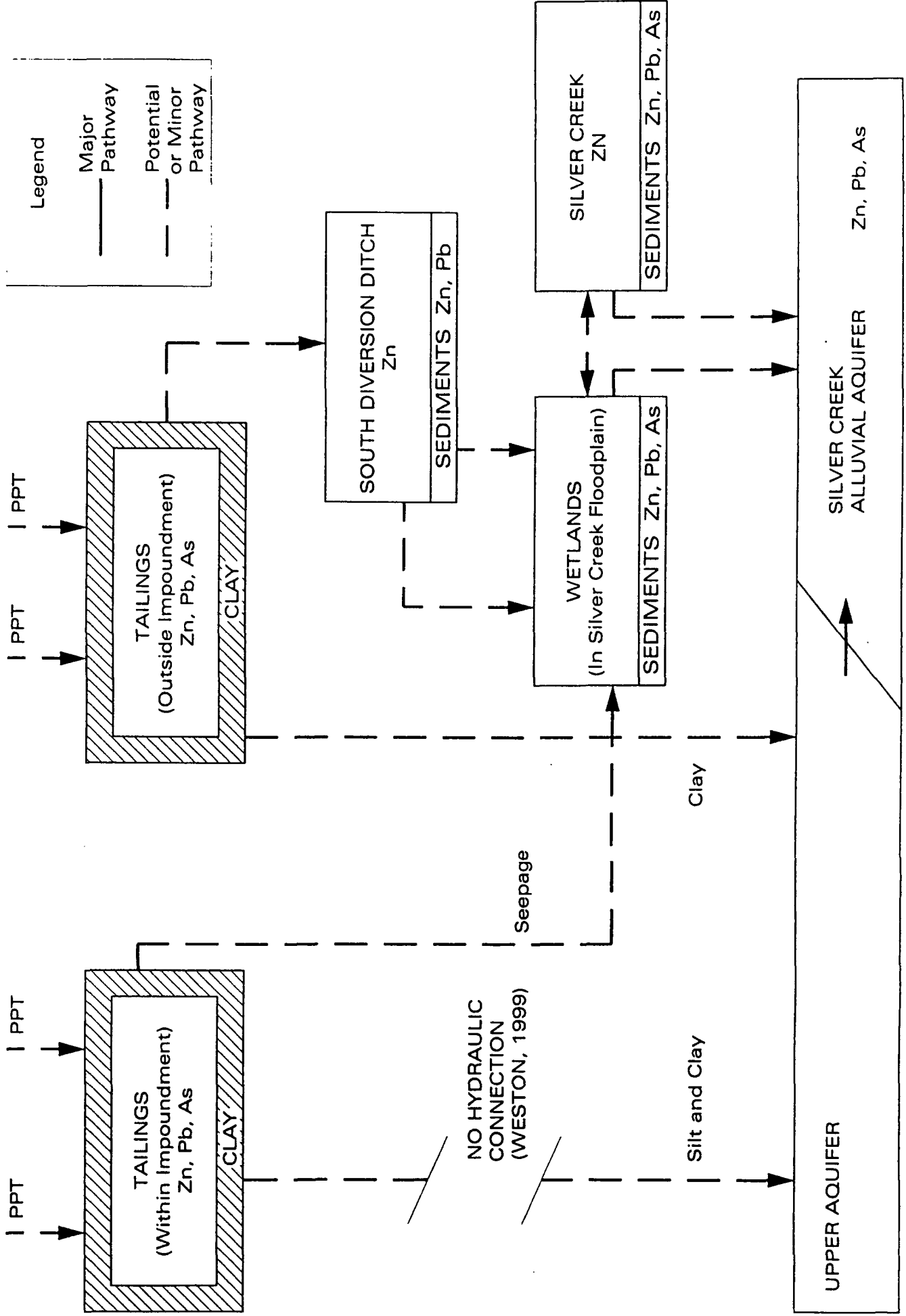
<b>RICHARDSON FLAT RI</b>	
FIGURE 4-5 ONSITE SOILS ANALYTICAL RESULTS MAP	
 RESOURCE MANAGEMENT CONSULTANTS 8138 SOUTH STATE ST. SUITE 2A MIDVALE, UT 84047 801-255-2626	OCTOBER 2002 RIFS-BASE.DWG

FIGURE 5-1

# Schematic Model of Contaminant Transport Pathways Richardson Flat



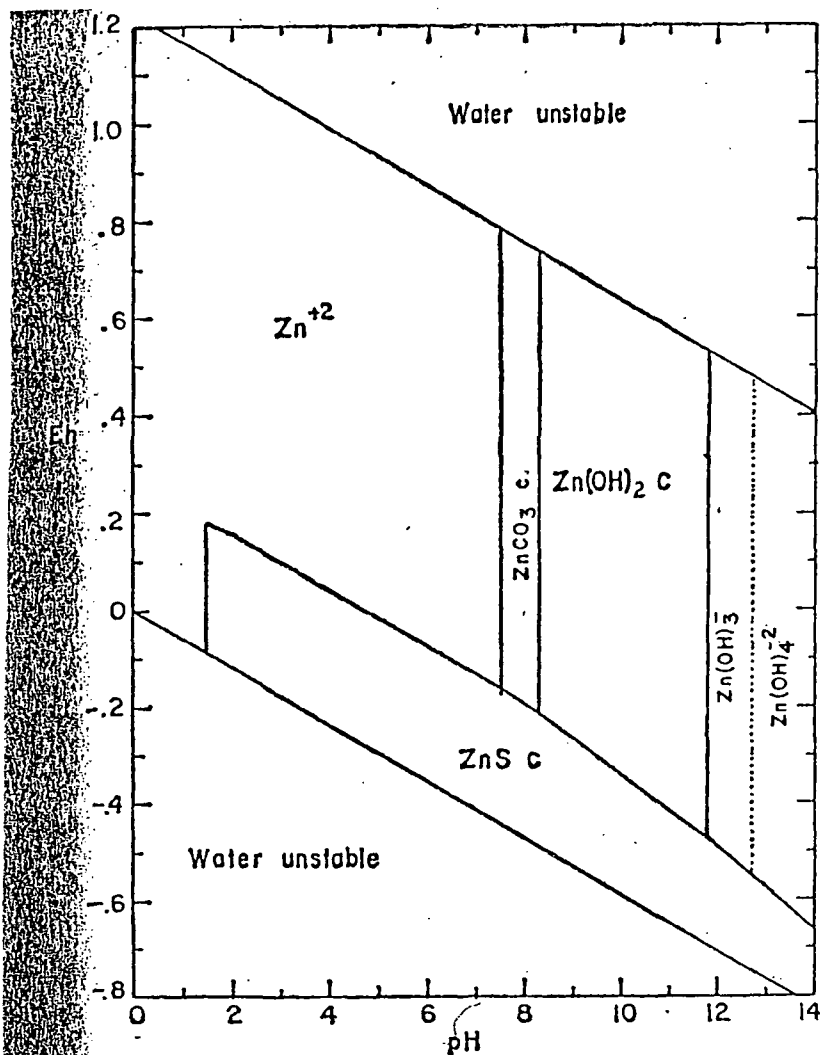


Fig. 2. Fields of stability of solids and predominant dissolved zinc species in system  $\text{Zn} + \text{CO}_2 + \text{S} + \text{H}_2\text{O}$  at  $25^\circ\text{C}$  and 1 atm pressure in relation to Eh and pH. Dissolved zinc activity,  $10^{-5}$  moles/l; dissolved carbon dioxide and sulfur species,  $10^{-3}$  moles/l.

## RICHARDSON FLAT RI

FIGURE 5-2  
pH/Eh PLOT

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801-255-2626

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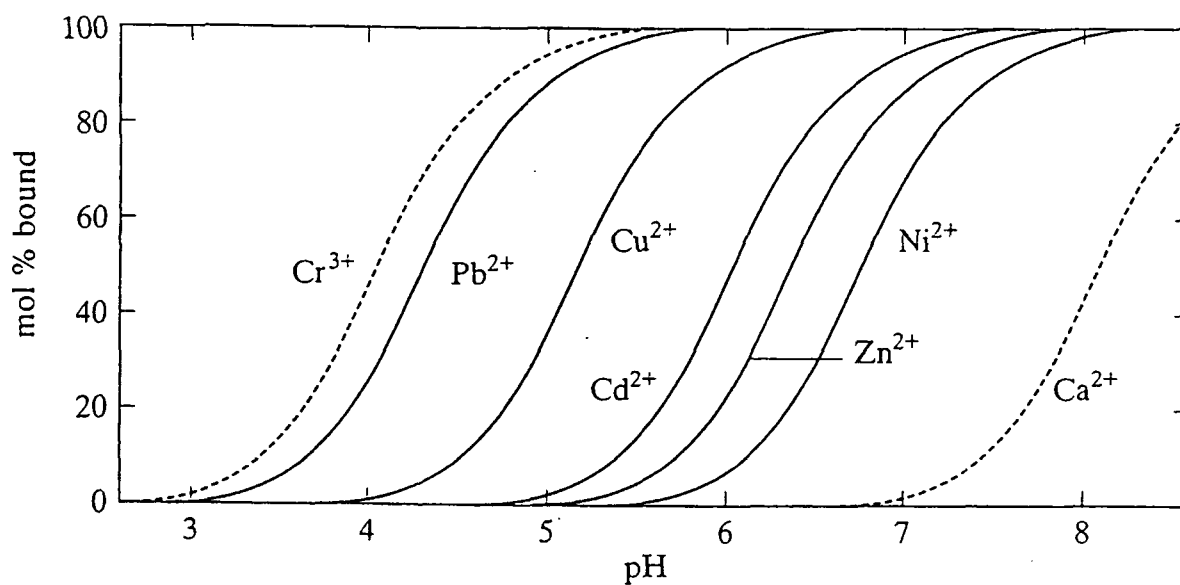


FIGURE 4-33 Surface complexation of dissolved metal ions as a function of pH (from *Aquatic Chemistry* 3/e, by Stumm and Morgan. Copyright © 1996 by Wiley Interscience. Reprinted by permission of John Wiley & Sons, Inc.).

## RICHARDSON FLAT RI

### FIGURE 5-3 SURFACE COMPLEXATION OF DISSOLVED METAL IONS

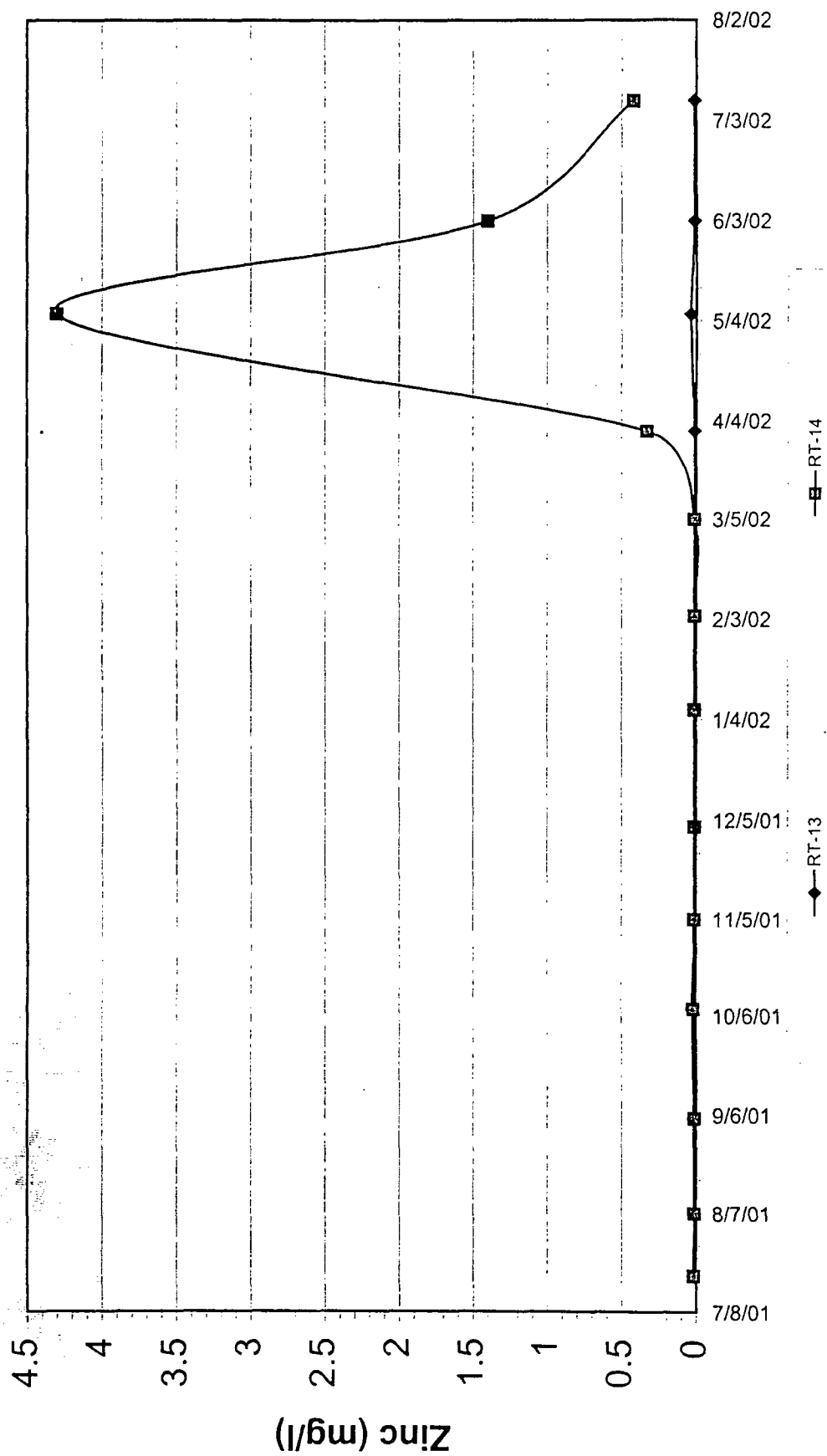
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8138 SOUTH STATE ST.  
SUITE 2A  
MIDVALE, UT 84047  
801-255-2626



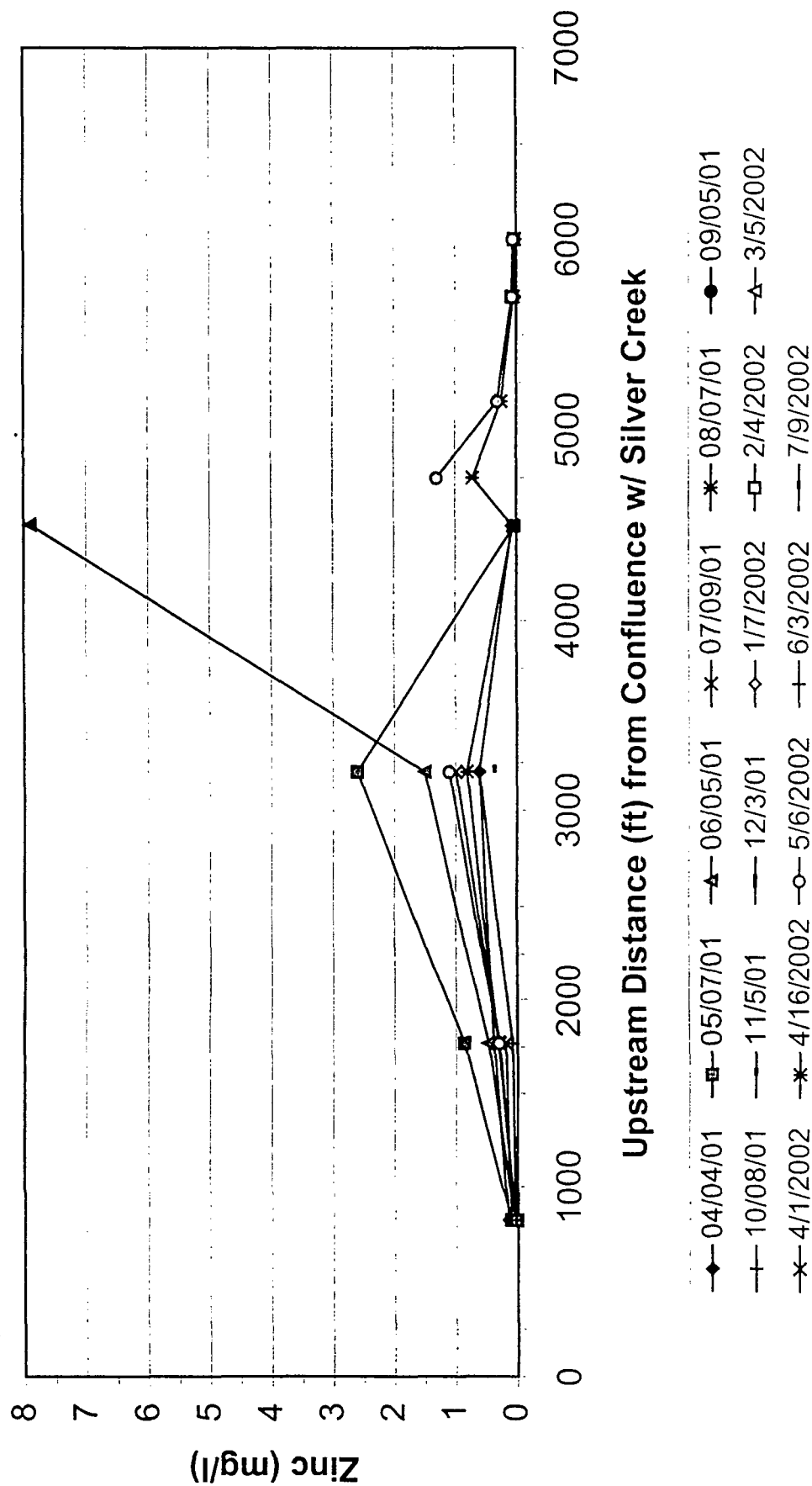
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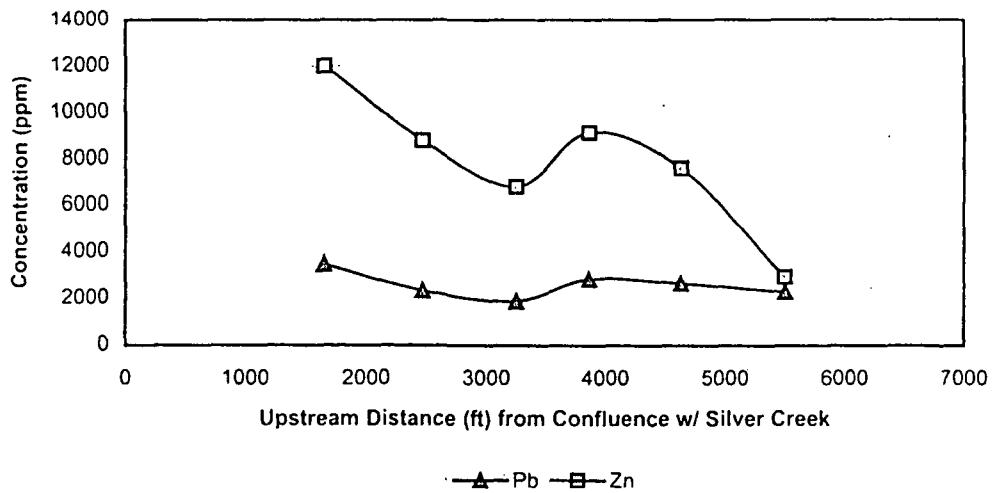
**Figure 5-4: Time Series Plot of Dissolved Zinc Concentrations in Upper Aquifer South of Tailings Impoundment**



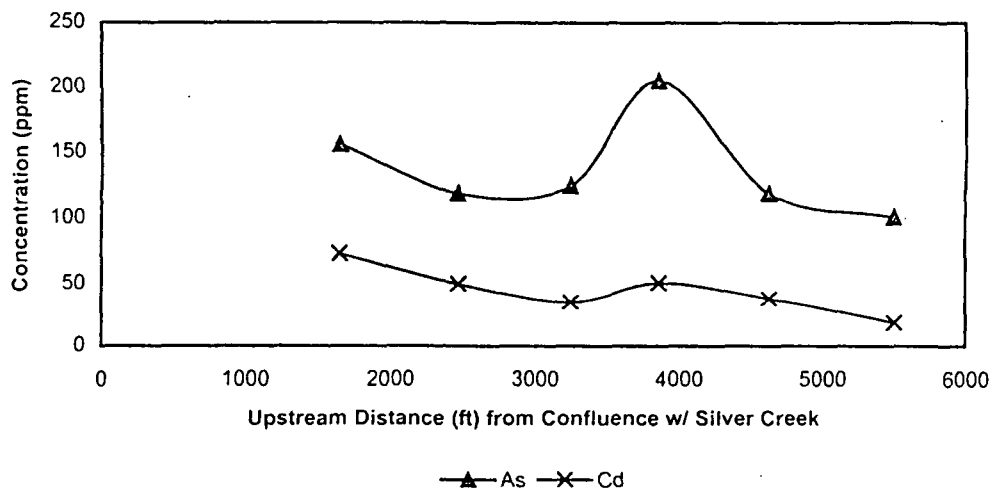
### Figure 5-5: Dissolved Zinc Concentrations in South Diversion Ditch



### Metal Concentrations in Sediments



### Metal Concentrations in Sediments



## RICHARDSON FLAT RI

FIGURE 5-6  
METALS CONCENTRATIONS IN SOUTH  
DIVERSION DITCH SEDIMENTS

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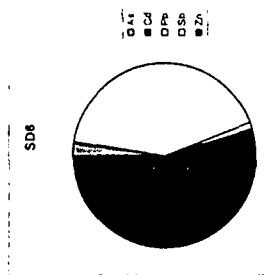
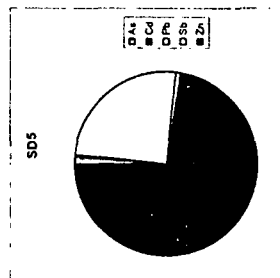
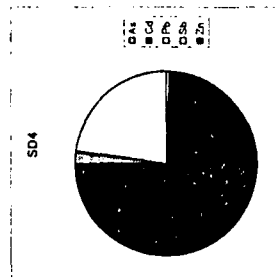
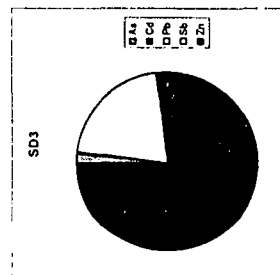
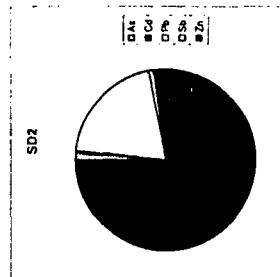
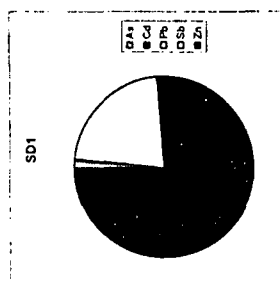
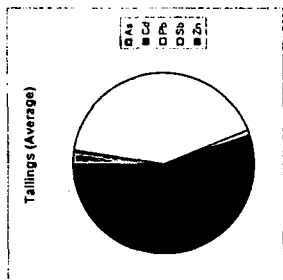
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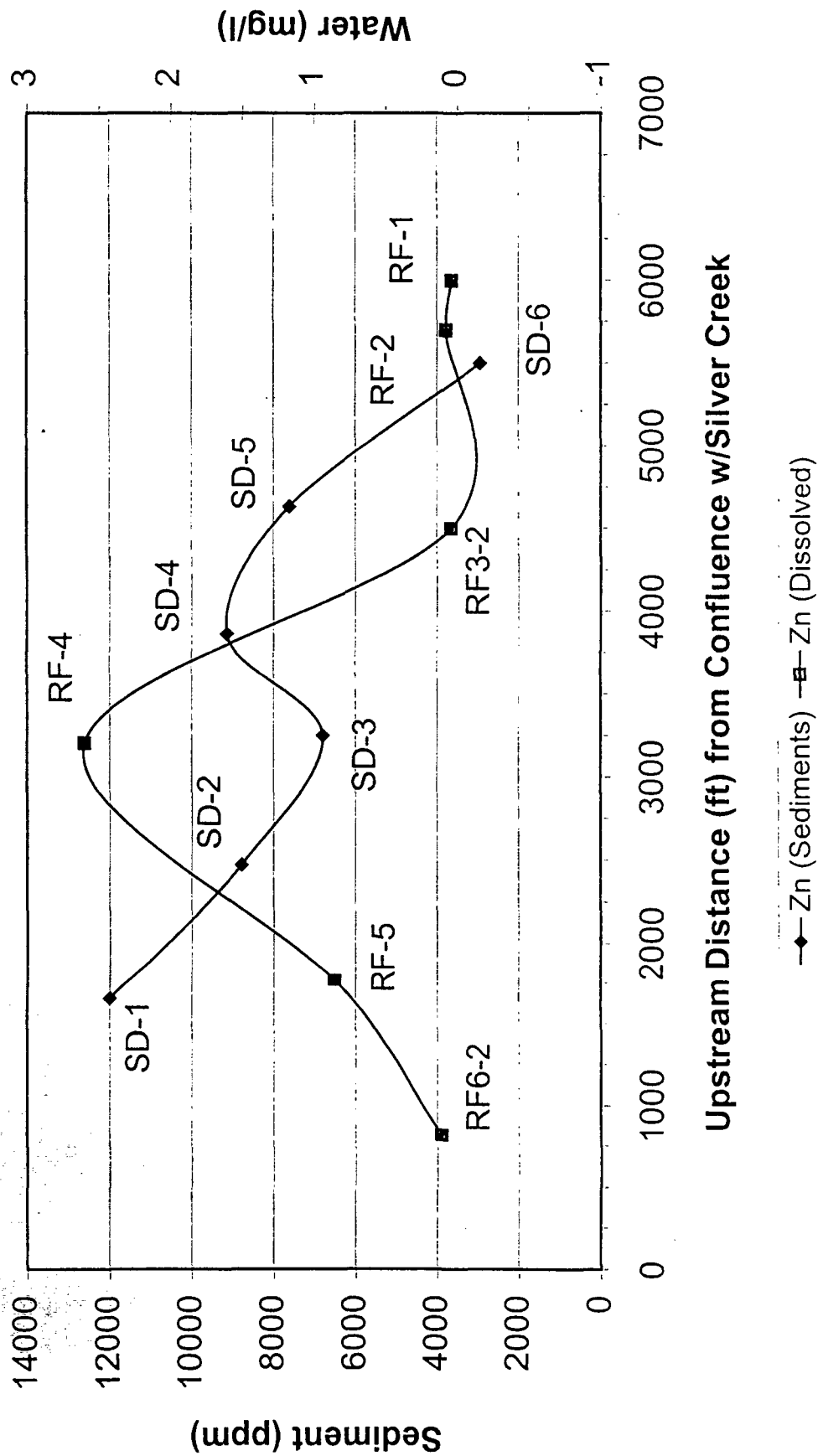
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Figure 5-7, Comparison of Trace Metal ratios in tailings and South Diversion Ditch Sediments

	Tailings Average	Sediment Average	SD1	SD2	SD3	SD4	SD5	SD6
As	254	138	156	119	125	205	119	101
Cd	34	44	73	50	35	51	38	18
Pb	4530	2578	3490	2330	1880	2840	2650	2280
Sb	110	64	72	53	36	65	97	63
Zn	5993	7878	12000	8780	6800	9140	7810	2940



**Figure 5-8**  
**Zinc Concentrations in Sediment (5/11/01) and Water**  
**(5/7/01) along South Diversion Ditch**



**Figure 5-9**  
**Lead Concentrations in Sediment (5/11/01) and Water**  
**(5/7/01) along South Diversion Ditch**

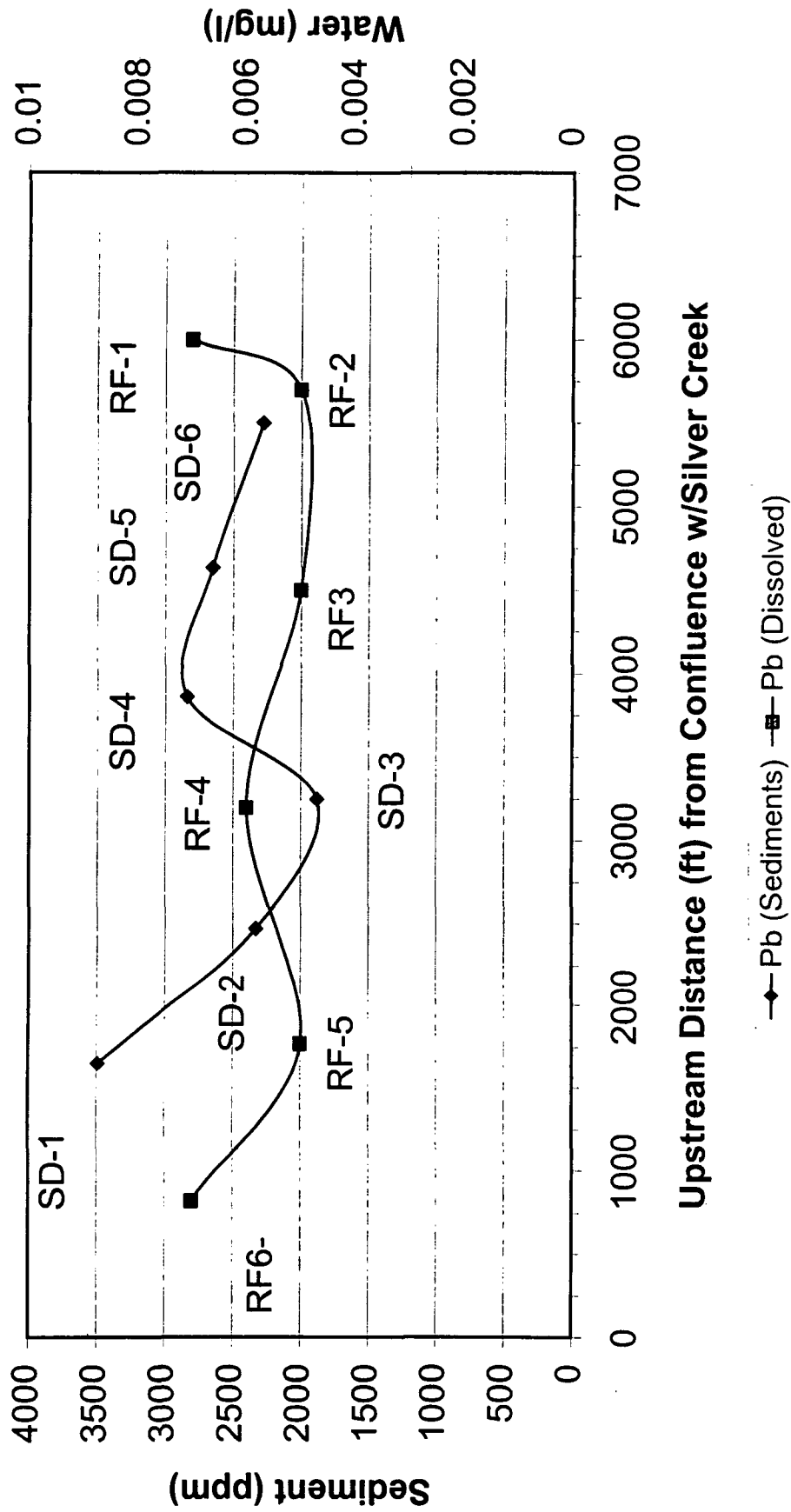


Figure 5-10, Plots of Dissolved Zinc Versus Key Chemical Parameters

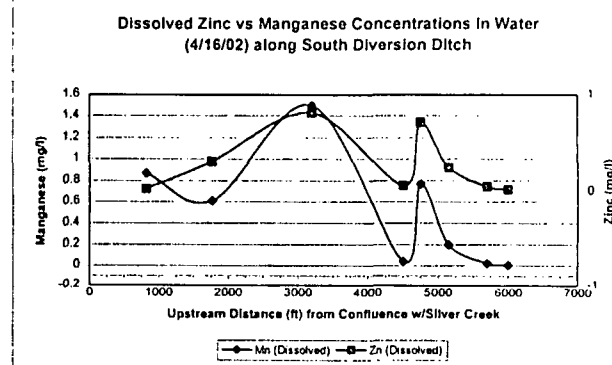
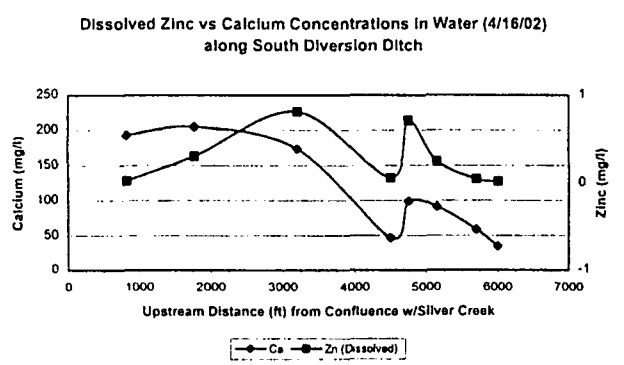
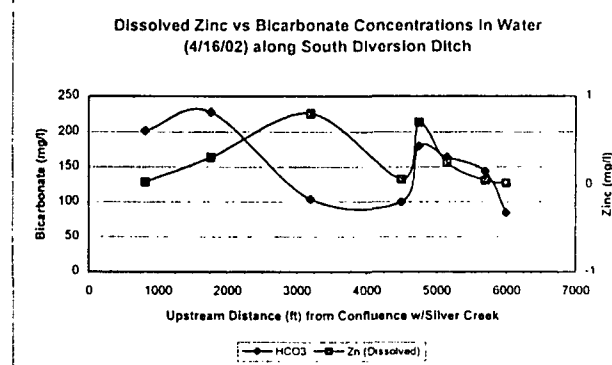
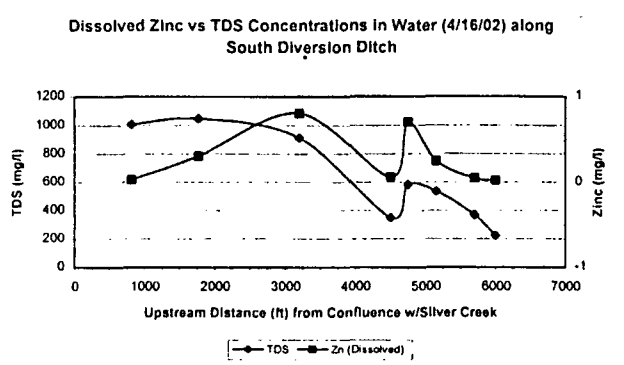
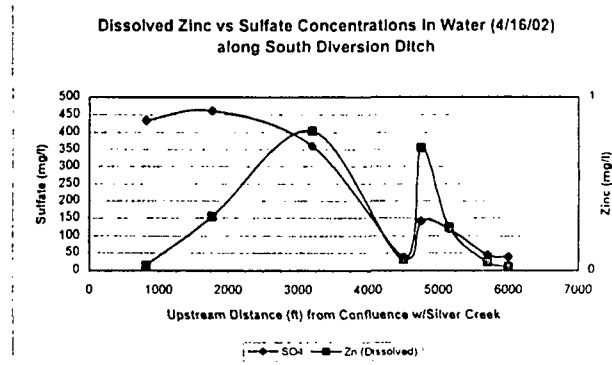
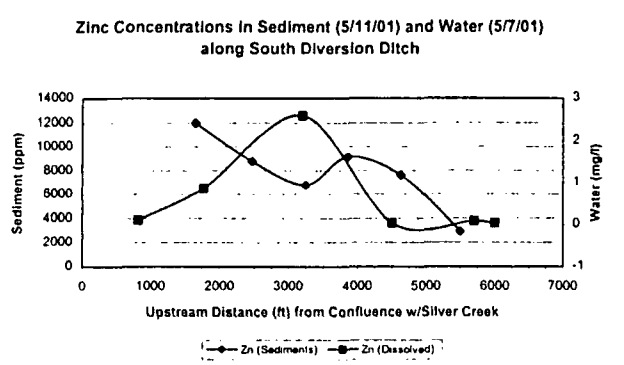
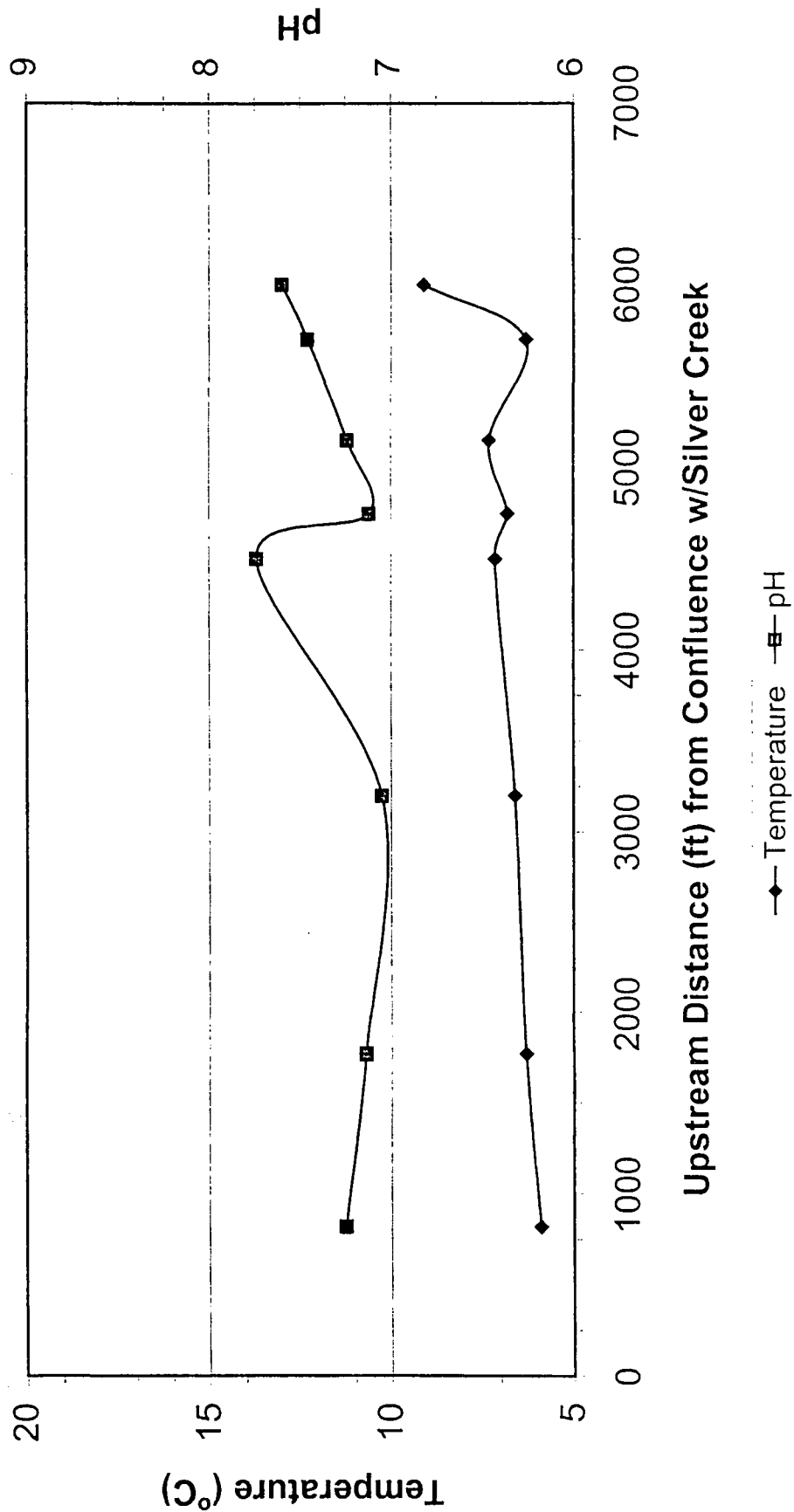
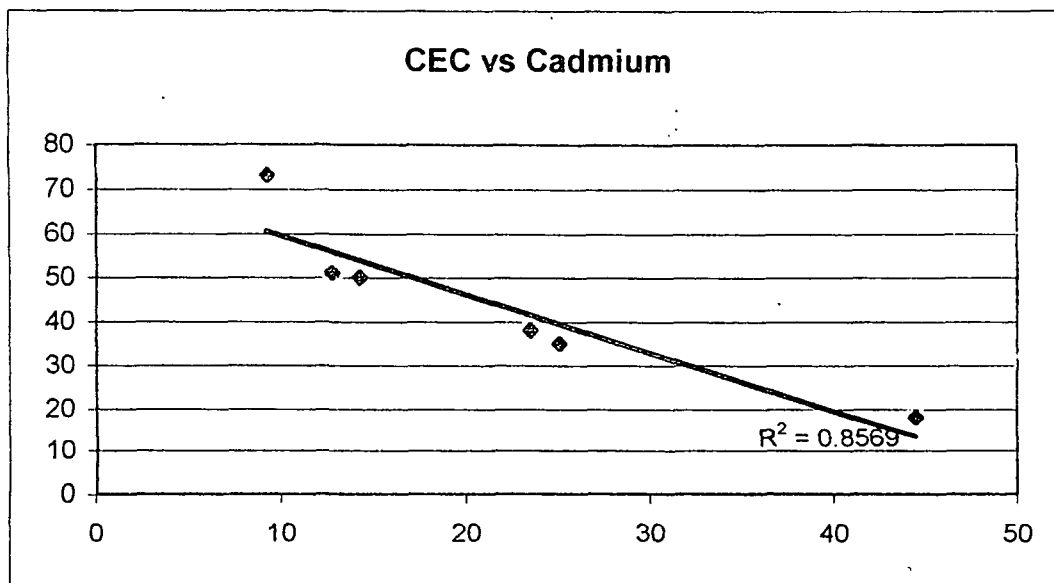
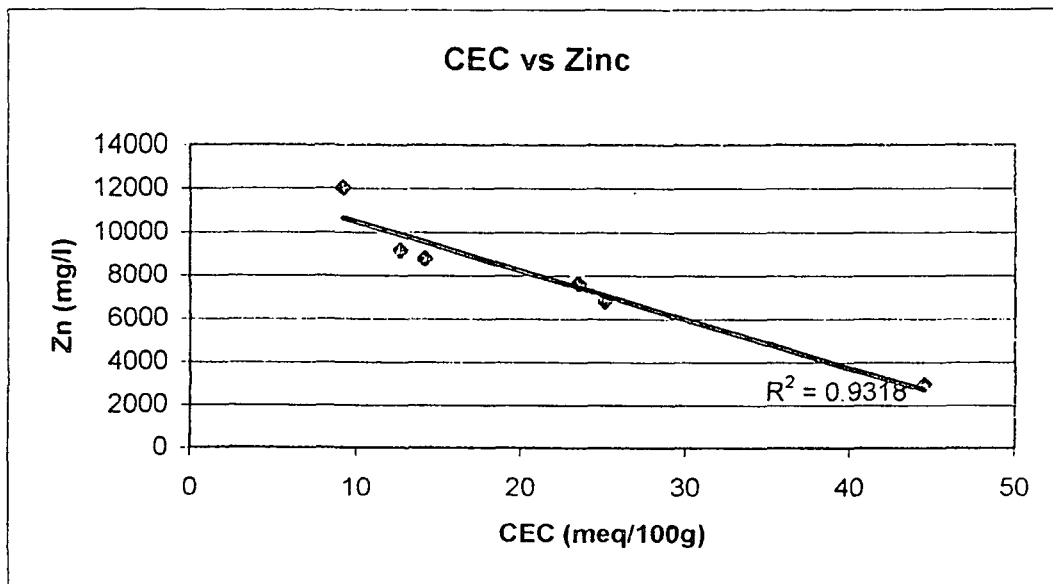




Figure 5-11  
 Temperature and pH in Water (4/16/02) along South  
 Diversion Ditch





## RICHARDSON FLAT RI

FIGURE 5-12  
CATION EXCHANGE CAPACITY VERSUS  
METALS CONCENTRATION IN SOUTH  
DIVERSION DITCH SEDIMENTS

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**Legend:**

- Silver Creek (GW)
- Tailings (GW)
- ▼ Diversion Ditch (SW)
- ▼ Silver Creek (SW)
- ◆ Floodplain Tailings
- ◆ Impoundment (GW)

**Figure 5-13**  
**Piper Plot of May 2002 Data**

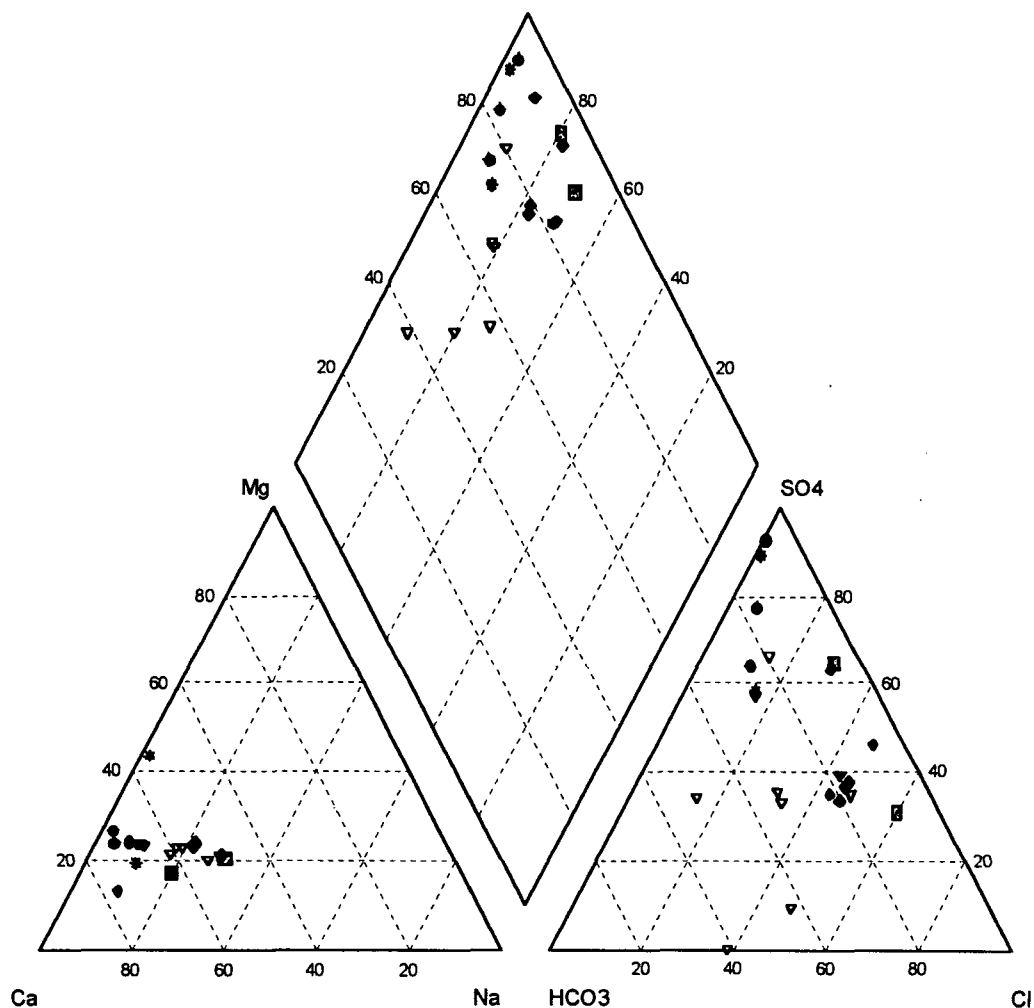
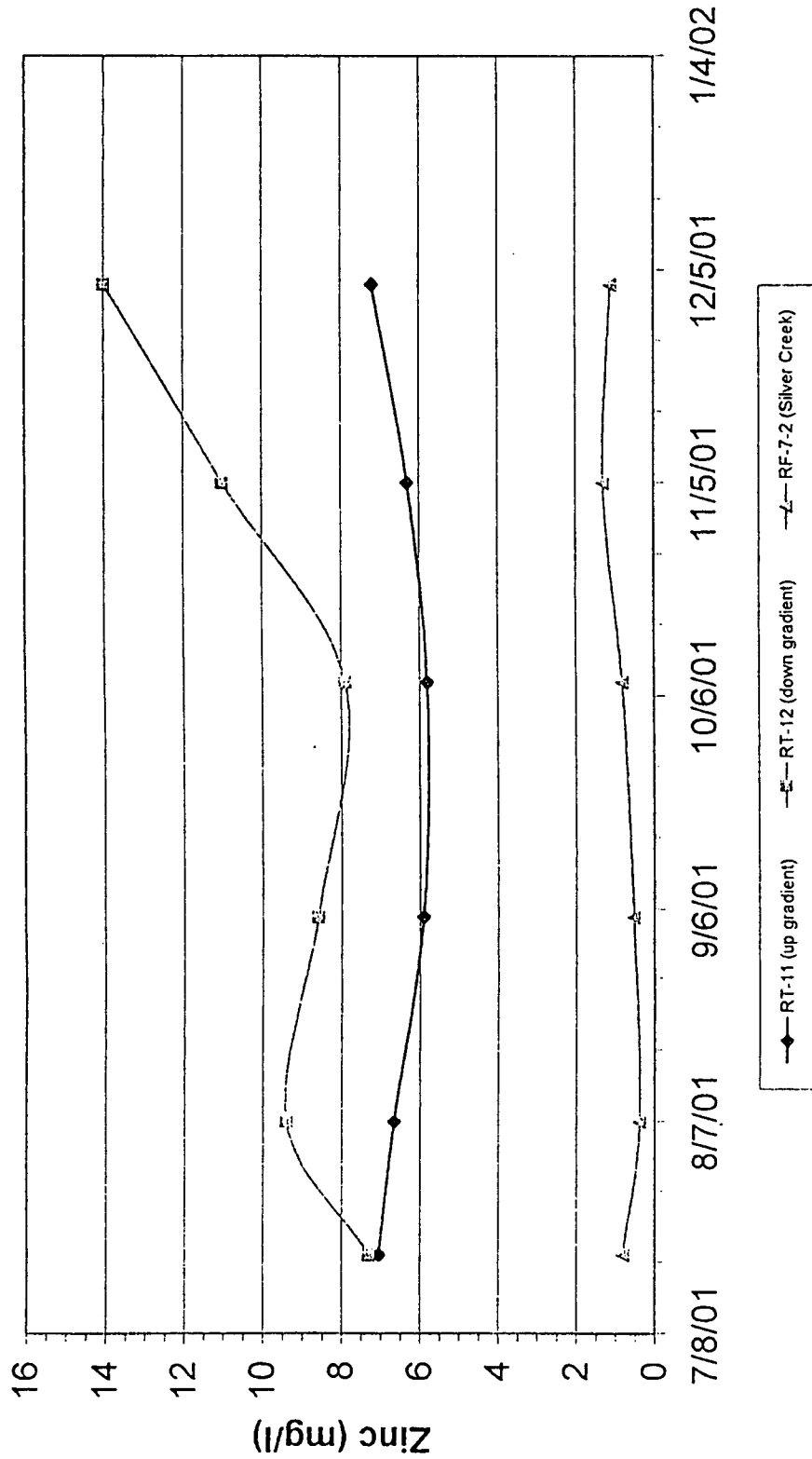


Figure 5-14: Time Series Plot of Dissolved Zinc Concentrations in Silver Creek Alluvium



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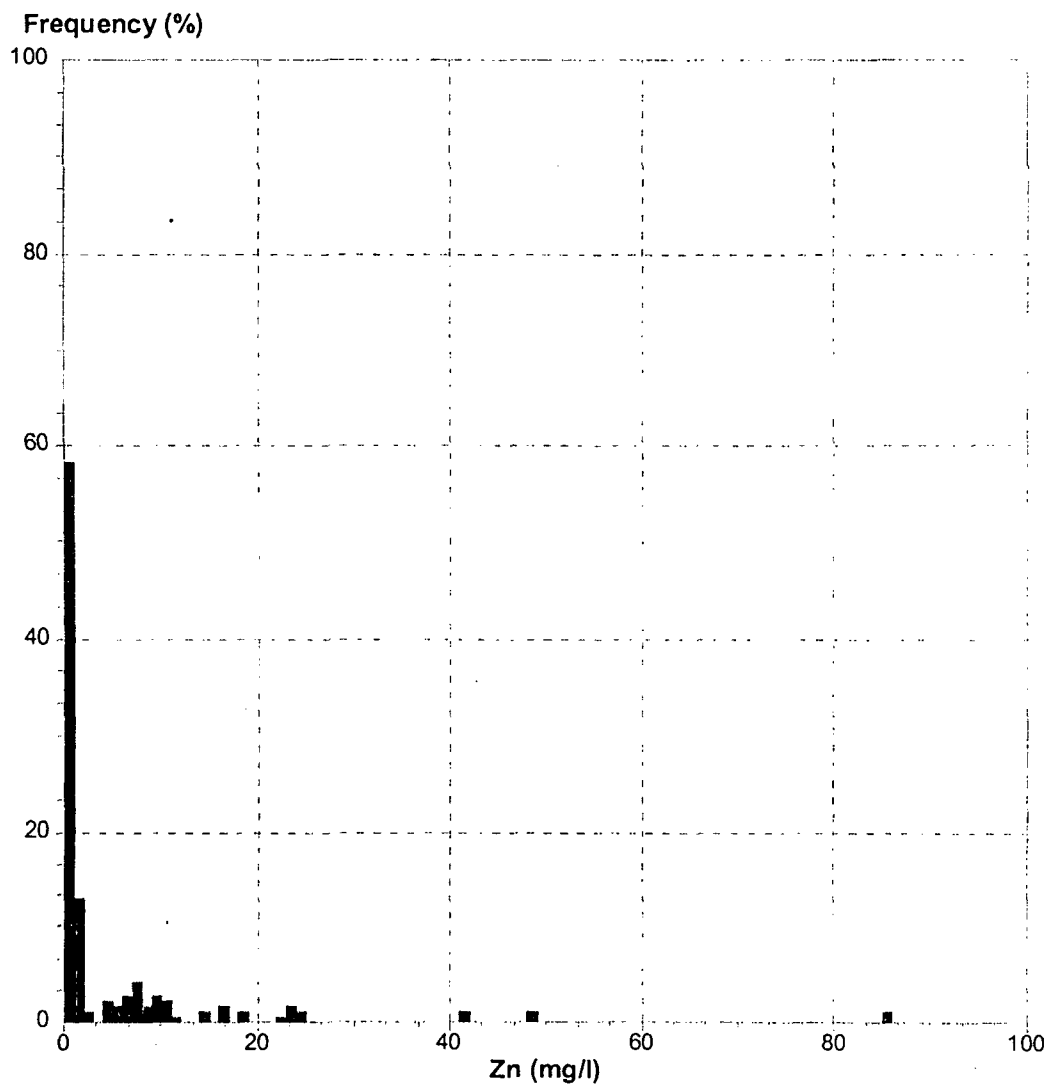
FIGURE 5-14  
TIMES SERIES PLOT OF DISSOLVED ZINC  
CONCENTRATIONS IN SILVER CREEK  
ALLUVIUM

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**Figure 5-15**  
**Histogram of Dissolved Zinc Concentrations**  
**(Including Tailings Impoundment and Floodplain Tailings Samples)**



**TARGET SHEET**  
EPA REGION VIII  
**SUPERFUND DOCUMENT MANAGEMENT SYSTEM**

DOCUMENT NUMBER: 2008740

SITE NAME: RICHARDSON FLAT TAILINGS

DOCUMENT DATE: 12/17/2002

**DOCUMENT NOT SCANNED**

Due to one of the following reasons:

- ☐ PHOTOGRAPHS
- ☐ 3-DIMENSIONAL
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- ☐ OTHER
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(Data Packages, Data Validation, Sampling Data, CBI, Chain of Custody)

DOCUMENT DESCRIPTION:

APPENDIX 1 thru APPENDIX 5 (See Table of Contents)  
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